INDICATORS TO EVALUATE PROGRESS *under the* GREAT LAKES WATER QUALITY AGREEMENT

prepared by the

INDICATORS FOR EVALUATION TASK FORCE
of the
INTERNATIONAL JOINT COMMISSION

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CHAPTER 1

INTRODUCTION AND BACKGROUND

THE AGREEMENT, THE COMMISSION AND THE TASK FORCE

Through the Great Lakes Water Quality Agreement, the governments of the United States and Canada (the Parties) have committed "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." For more than two decades, numerous programs and measures have been undertaken towards this purpose.

Under Article VII of the Agreement, the International Joint Commission was given responsibilities to:

- Collate, analyze and disseminate data regarding the quality of the boundary waters of the Great Lakes system and pollution entering them.
- Collect, analyze, and disseminate data concerning the General and Specific Objectives and programs established pursuant to the Agreement.
- Provide advice and recommendations on matters related to the quality of the boundary waters of the Great Lakes system.

To fulfill its mandate to evaluate Agreement progress and provide advice to governments, the Commission requires data and information. From the initial signing of the Agreement in 1972 until 1987, these tasks involved the analysis of substantial quantities of data provided by the Parties. These data on ambient conditions and pollutant loadings in effect lead to state-of-the-lake reports. Historically, governments provided such data through the Commission's advisory boards.

With the 1987 amendments to the Agreement, responsibility for reporting on the condition of the lakes and remedial programs shifted to governments, which developed bilateral mechanisms such as the State of the Lakes Ecosystem Conference (SOLEC). Also, governments have been seeking to identify the core needs of their data collection and other programs. The Commission's advisory bodies have, in the meantime, tended to focus more on analysis and policy issues, and have expressed a need for revised guidance on the Commission's desired data activities.

In response to these changes in the way that functions are organized and carried out, the Commission identified, as a priority activity, the consideration of its data and information needs, and the identification of indicators to evaluate Agreement progress. Consequently, it established an Indicators for Evaluation Task Force in 1993 to assist in reviewing these requirements and to develop a framework within which to conduct its evaluation and develop advice. The Commission, in particular, suggested a focus on state-of-the-lake reporting and consideration of integrative indicators of ecosystem integrity.

INDICATORS AND THE AGREEMENT: EVOLUTION IN UNDERSTANDING AND RESPONSIBILITIES

"Evaluation of progress" can be, and has historically been, interpreted in two distinct ways: in terms of *programmatic* progress under various sections of the Agreement, and in terms of improvement in the environmental state or *condition* of the Great Lakes basin ecosystem. Among other things, Article VII of the Agreement requests the Commission to evaluate the operation and effectiveness of "programs and other measures undertaken pursuant to this Agreement. ..." While it is important to assess administrative decisions and programmatic actions that influence environmental outcomes, program effectiveness ultimately should be reflected in improvements in Great Lakes environmental quality. These improvements can be measured using state-of-the-lake indicators. A comprehensive evaluation of Agreement progress requires both interpretations of "evaluation of progress."

Recognizing that the ecosystem is complex and dynamic, the Task Force undertook to develop an appropriate framework and indicators which would facilitate the Commission's evaluation of Agreement progress. The framework, desired outcomes and indicators presented later in this report focus principally on environmental conditions, but recognize that changes in the state of the Great Lakes ecosystem implicitly reflect the effectiveness of programs and measures undertaken to fulfill the obligations of the Agreement.

Further, the Task Force believes that a focus on a "traditional" understanding of how to evaluate Agreement progress is too narrow. Such progress has been generally associated with governmental actions. Yet much of the progress and many of the relevant programs and activities currently underway -- and anticipated in the future -- are in the private and voluntary sectors. These include voluntary undertakings by industry; other actions are community based. Hence, a broad scope of program assessment must be undertaken.

At the same time, the ecosystem approach, espoused by the 1978 Agreement, has been broadly interpreted both by the Commission and increasingly by governments. This interpretation inevitably results in a wider scope of assessment needs concerning the quality of the Great Lakes ecosystem than was conventionally understood during the first decade of the Agreement. Relevant concerns now include the biological, economic and social factors affecting, and being affected by, the quality of the aquatic part of the ecosystem, as well as the traditional physical and chemical phenomena. More recently, the fact that humans are part of the ecosystem and emerging knowledge of the impacts of toxic chemicals on human health, while not yet universally accepted as significant issues, have become part of the ecosystem paradigm for many scientists, the public and the Commission.

The ecosystemic approach, as well as social cost, equity and other considerations, are pushing environmentally relevant data and policy in new directions. For example, the objectives of governments and other interest groups are evolving from narrow regulatory and remedial targets to preventive programs and "sustainable development," which is defined as a manner of conducting human activity that does not sacrifice the economic, environmental or social well-being of future generations in order to provide for the current generation. Furthermore, the relevant spatial and temporal scales are seen to encompass widening ranges, from the local and immediate to global and intergenerational concerns.

Socio-economic factors determine, in large measure, human impacts on the Great Lakes basin ecosystem. The Agreement does not explicitly address this concept. However, as expressed through its *Sixth* and *Seventh Biennial Reports*, the Commission believes that socio-economic considerations are implicitly embedded in, and a logical interpretation of the principles underlying the Agreement. Therefore, the Task Force's advice about evaluation of progress includes socio-economic considerations and the concept of sustainable development.

The Commission and the governments have come to recognize that some of the solutions to environmental problems (and therefore the information needed to track them) lie not only at the regional, national and continental scale, but in multilateral, transglobal organizations, both those specifically oriented towards environmental issues and increasingly those dealing primarily with trade and development issues. Perhaps the most complete presentation of these wide-ranging considerations is found in Agenda 21, the product of the United Nations Conference on Environment and Development in Rio de Janeiro.

These trends are reinforced by the demands from public and other interest groups for involvement in Great Lakes environmental issues and the consideration of additional concerns such as radionuclear, sectoral, economic and cultural issues. The scope of this widening vision of ecosystem "integrity" is expressed in documents such as the Great Lakes Fishery Commission's Vision Statement, the Great Lakes Water Quality Board's Vision Statement (subsequently commended to governments by the International Joint Commission), the Council of Great Lakes Research Managers' comprehensive Ecosystem Model, and

especially the Great Lakes Ecosystem Charter. The charter, a multipartite document spearheaded by the Great Lakes Commission, sets out a substantial number of goals and philosophies to which the wide range of signatories have been asked to subscribe as a reflection of a desired approach to Great Lakes management both generally and within their own mandates.

The ecosystemic approach, initially championed by the International Joint Commission, is now broadly supported in the literature and in reality. As a result, the Commission and its advisory boards cannot ignore the implications of this broader vision of environmental assessment on their data needs. Also, there appears to be an increasing perceived need for the Commission to provide socially and technically relevant situation reports and analyses for public consumption.

These trends have led to this reassessment of the Commission's data and information needs. Not only do they complicate the issue of measuring progress, they reflect at least two quite different perspectives that need to be satisfied:

- A comprehensive listing of Commission data and information needs that can be forwarded to the governments and the Commission's own advisory boards as a basis for planning and dialogue on the capacity to provide such data and information.

- A limited list of indicators that can be used to signal quickly and easily the state of the Great Lakes and of the implementation of programs under the Agreement.

On the surface, these two objectives seem inconsistent. However, if an approach that sees the possibility of a nesting or hierarchy of indicators is attempted, then both objectives might be met. This is the approach this paper attempts to address.

From the foregoing presentation of the ecosystem approach, an image of complexity emerges, to the point that policymakers are overwhelmed. This suggests a demand for guidance on what to consider, and a need for clear, easily understood indicators of progress that capture a broad spectrum of issues in a few key and even dramatic figures.

The ecosystem encompasses so many "grains of sand." To implement an ecosystem approach, a focus on individual grains of sand, such as through RAPs and LAMPs, may be a viable way to think globally but act locally.

THE TASK FORCE'S INVESTIGATIONS

A great deal of work is ongoing in both Canada and the United States, as well as internationally, on the development of indicators for a wide range of issues and applications. The Task Force reviewed these approaches, with respect to characterizing the state of the Great Lakes and those being taken in multilateral forums (such as the Organization for Economic Coöperation and Development) in identifying appropriate indicators of environmental quality. This review facilitated the Task Force's development of a base on which to evaluate Agreement progress. The Task Force addressed a range of those initiatives in an Issues Definition Session, held December 2-3, 1993 and through the assembly of background information.

Appendix A summarizes approximately 20 relevant initiatives, including several with a Great Lakes focus; others are listed in the bibliography. A review of these initiatives indicates that, although their goals may be articulated or focussed somewhat differently, many have an intent akin or equivalent to the Agreement purpose. The Task Force accordingly extracted appropriate material in developing its advice to the Commission.

The Task Force also noted that the process to identify required data and to develop an operating framework is dynamic and should, therefore, involve continuing dialogue among those who assess data and information to ascertain ecosystem status, and those who evaluate Agreement progress. Further, due to the Agreement's ecosystemic approach, the pertinent "data and information" must include not only "traditional" physical, chemical and biological considerations, but also socio-economic ones.

As a result of its initial review of current indicator initiatives, as well as its Issues Definition Session, the Task Force developed a preliminary structure or framework within which to identify and use specific indicators. That structure provided a basis for a workshop, held on October 5-6, 1994, to identify specific indicators that could be used to evaluate progress under the Agreement. The workshop was structured around five key stress categories (non-native species, nutrients, persistent toxic substances, physical change, and human activity and values) that impact desired conditions or healthy outcomes for the ecosystem. As an operating premise, the Task Force assumed that indicators can be identified to characterize both the stresses and the status of the ecosystem *vis-à-vis* the desired conditions or outcome. Through selection and application of appropriate indicators, the Commission can fulfill its obligation to evaluate progress under the Agreement and develop its advice to governments.

Based on advice received at the workshop, the Task Force developed and circulated, in May 1995, a draft report to workshop participants and to members of the Commission "family" (Water Quality Board, Science Advisory Board, Council of Great Lakes Research Managers and others). A total of 43 responses (identified in Appendix B) provided thoughtful insight and feedback, which assisted the Task Force in refining this report.

The Task Force carefully considered the reviewers' detailed advice. The product is this report which the Task Force hereby submits to the Commission.

- Chapter 2 describes the concept of indicators.
- Chapter 3 presents organizing principles and methodology.
- Chapter 4 presents a framework for evaluation of Agreement progress. The framework relates the Agreement purpose -- ecosystem integrity -- to desired outcomes, indicators to characterize each desired outcome, associated data and information to support each indicator, and relevant stresses.
- Chapter 5 identifies nine selected desired outcomes for the Great Lakes basin ecosystem, along with representative indicators and associated measurements that can be used to evaluate Agreement progress.
- Chapter 6 presents conclusions and recommendations.

RELATIONSHIP WITH SOLEC INITIATIVE

A key consideration in the treatment of the Commission's data needs, and in any request for the Parties to provide data as required by Article IX of the Agreement, is the relationship of the Commission's data needs and those of the Parties. Under the terms of the Agreement, the Parties and the Commission have different responsibilities. The Parties undertake programs and report their progress, and the Commission evaluates the adequacy of that progress.

As a major initiative in fulfilling their reporting responsibility, the Parties have initiated a State of the Great Lakes Ecosystem reporting system, based on a biennial conference (SOLEC). The SOLEC initiative provides a framework for a broad assessment of the state of the Great Lakes. The first conference, held in October 1994, provided several binational background papers and a useful *Integration Paper* that led to the report, *State of the Great Lakes 1995*. This documentation, to some degree negotiated in its analysis and severely constrained by data availability, does a credible job of integrating a wide range of information for an assessment of ecosystem status and/or health. In terms of binational assessment efforts, the first SOLEC was experimental and pioneering in its attempt to take a truly ecosystemic approach. For the first time, a binational effort seriously attempted to integrate human measures, including physical and socio-economic parameters, with an expanding suite of biophysical ones. It incorporated concerns for natural habitat and species diversity as well as measures of ambient water quality. There are indicators both of ecosystem *conditions* and *stress*, including measures of:

- The state of aquatic communities
- Human health and environmental contaminant risks
- The state of aquatic habitat and wetlands
- Nutrient stresses
- Contaminant stresses
- Economic stresses and mitigating activity.

This list was viewed by the SOLEC team as a preliminary list of sub-systems or components. Work remains to refine the indicators and to provide sufficient current data, particularly in the areas of human health and the economy. Furthermore, *ecosystem integrity* (at the scale of the Great Lakes basin), as an emergent property of the whole watershed and beyond, ought eventually to be characterized by some macroscopic (whole-system) indicators of integrity as well as by its various, independently expressed sub-systems and/or components.

In many ways, the philosophy and the practice in the SOLEC initiative are highly congruent with the Task Force's work. The approaches to scale, scope and integration of data are similar. Much of the information in the *Integration Paper* and the subsequent *State of the Great Lakes 1995* report -- indicators, stresses and descriptive status -- can easily be integrated or utilized in the Task Force's proposed evaluative framework. Indeed, it is heartening that much of the requisite information the Task Force considers necessary to evaluate Agreement progress is also identified by the Parties.

On the other hand, the Commission's goals and data needs start from a different base. The Commission is required to undertake an evaluation of activities including monitoring, surveillance and analysis of data, in light of the Parties' purpose as stated in the Agreement, "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem," and does so within an ecosystemic approach to water quality. While the Task Force considers this to be somewhat analogous to the "ecosystem health" goal given in the *Integration Paper*, the Task Force has developed its own concept of "aquatic

ecosystem integrity," as discussed in Chapter 4, in terms of a hierarchical series of desired outcomes, associated indicators and measurements that can be used to evaluate progress toward, and achievement of the desired outcome, and impacting stresses.

The development of indicators and evaluation of progress are dynamic, interactive and evolving processes that will require coöperation between the governments and the Commission. The Task Force hopes this report will provide the Commission with useful guidance to encourage governments and others to consider a set of desired outcomes and associated indicators, as well as the data and information necessary and sufficient to evaluate progress under the Agreement.

The Task Force believes that attention to desired outcomes will provide policy focus to Agreement efforts and their assessment. On a different plane, the Task Force believes that its function, and that of the Commission, includes, in some cases, the setting of indicators for various outcomes that may go beyond the current capacity of the SOLEC and supporting data procedures. Although this approach has been tempered by current realities (such as currently available data and funding), the Task Force felt it necessary, in some cases, to indicate data needs that go beyond these realities and suggest increased data collection and analysis efforts in some areas.

In summary, the Task Force views the SOLEC process as an appropriate way for governments to develop reports on the state of the Great Lakes and Agreement progress, and that substantial progress has been made in developing a useful framework and reporting mechanism. Under the proposal presented in this report, the SOLEC and Commission data needs are philosophically attuned and similar in scope in terms of the range of indicators, although some specific differences are evident that might be useful in refining future SOLEC efforts. Yet, in addition to such potential specific modifications and the incorporation of expected data refinements, such reports could be even more useful if they focussed on clearly defined desired outcomes, identified specific indicators for each, and provided measurements to support the indicators and the conclusions regarding progress toward desired outcomes.

CHAPTER 2

INDICATORS

DEFINITION

An indicator provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. It is a sign or symptom that makes something known with a reasonable degree of certainty. An indicator reveals, gives evidence. Its significance extends beyond what is actually measured to a larger phenomenon of interest.

The U.S. Intergovernmental Task Force on Monitoring Water Quality (ITFM) defined an environmental indicator as a:

> "measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality."

This definition is particularly useful when the "measurable feature" is associated with an explicit goal or desired outcome. Environmental indicators encompass a broad suite of measures, including tools for assessment of chemical, physical and biological conditions and processes at several scales (discussed in Chapter 3).

The word "indicator" has been generally missing in ecological literature until only very recently. Harris and Scheberle reviewed twelve recent college ecology textbooks and found only one that presented a broad discussion of the term as it is being used today. Other sciences, including the social sciences, have more commonly used indicator concepts and terminology.

PURPOSE

Environmental indicators communicate information about the environment and about the human activities that affect it. When communicated effectively, the indicator highlights problems and draws attention to the effectiveness of current policies. The target audiences are the public and the decisionmakers (*i.e.* governments). To command their attention, indicators must be relevant, and they must communicate value. Choosing an indicator reflects a set of values that is perceived as being important. Examples of effective indicators for certain purposes are the Dow Jones industrial average, the gross national product, incident solar radiation, and pollen count.

Key to an indicator's selection, acceptance and usefulness is consultation with stakeholders throughout the procedure to develop environmental indicators and indicator packages. Consensus -- both technical and public -- is essential if institutions are to invest further in indicators.

The indicators and indicator packages should characterize specific desired outcomes that answer questions such as: *Are the lakes getting better? Have we achieved fishable,* swimmable and drinkable conditions?

A particular challenge is to make the indicator user friendly so that the desired outcome to which it is attached gets the attention it deserves. For example, the loss of a "bug" which is a key component of the food web may not be glamorous, but could have a devastating economic impact through consequent loss of a recreational fishery. Policymakers must be able to understand the value of the bug to the ecosystem, the impacting stresses, and what must be done to relieve the stress and reverse the condition that could have the adverse economic impact.

> Indicators are not an end in themselves. Rather they are tools that, used with wisdom and restraint, can build support for needed change.

Indicators must convey that the environment is important and that appropriate policies can be implemented to ensure necessary restoration and protection. Indicators must therefore provide objective information in order to identify the cause of a problem and its relative weight. In this way, environmental indicators are intimately linked with strategic planning. Because public opinion shapes decisionmaking, indicators must illustrate not only environmental trends but also the effectiveness of present policies, leading or pointing the way to alternative or better approaches.

Indicators must quantify information to make its significance apparent, and must simplify that information to improve communication. While indicators must be easy to grasp, balance is important. Indicators must also be chosen and presented in such a way to avoid misleading impressions of the cause of a particular environmental condition being addressed, or the relative complexity of the condition. Finally, indicators can help us recognize that the ecosystem (and certain desired outcomes) is not totally within the control of humans.

RELATIONSHIP TO THE GREAT LAKES WATER QUALITY AGREEMENT

In a straightforward, understandable form, indicators must communicate specific information about progress under the Agreement and, hence, indirectly comment on the adequacy of programs and policies to achieve Agreement goals. Indicators should answer such questions as:

- How clean is the environment, *i.e.* what are present ambient conditions?
- Are trends in the right direction? How quickly are we making progress toward achieving the desired outcome?
- What and where are the causes (stresses)? Have cause-effect relationships been demonstrated?
- Are present protection, restoration and pollution prevention programs, policies, processes, and practices working? Are humans engaging in the required environmental actions? Will they achieve the desired outcomes?
- Can we detect the onset of deleterious conditions and react before significant impact occurs?

Indicators for the measurement and evaluation of progress under the Agreement are an example of what are sometimes termed "policy" indicators, because they are designed to measure progress toward policy goals. The Task Force has placed an emphasis on policy-related indicators, akin to the approach being followed by the Netherlands and adopted by the Organization for Economic Coöperation and Development (OECD).

Indicators can provide guidance on needs, priorities and policy effectiveness, but only if decisionmakers consider them useful and use them. If decisionmakers are responsive to comments and insights about programs and policies, then policy evaluation, formulation and effectiveness will be improved, as will the end points or goals of those policies.

CHARACTERISTICS OF INDICATORS

Successful indicators possess a number of characteristics. They are:

- User driven, *i.e.* useful.
- Policy relevant, *i.e.* pertinent. Is the indicator driven by policy for budget and/or management purposes?
- Highly aggregated: many components but, in the end, few in number.
- Able to integrate information in a way to serve as a barometer of the general "health" of the system.
- Able to quantify and simplify information.

- Flexible: Amenable to reconsideration as conditions change, new issues arise, and responses to some problems begin to work.

- Capable of reflecting a spectrum of conditions ranging from the living system back through the chemical and physical environments to the sources of stresses.

Indicators require a framework within which information can be collected, assessed and reported. The Task Force structured its view of indicators around the PSR (pressure-state-response) model, developed by Canada and adopted by OECD. A PSR-type model is useful because of its simplicity and wide acceptance and because it can be applied at any scale (see Chapter 3). The main categories in the PSR framework are:

- Indirect and underlying direct **pressures**, including human activities that cause environmental change.

- The physical, chemical and biological condition, or **state** of the natural world, as measured at different scales (global, regional and local), plus human health and welfare.

- **Responses** or changes in policy or behaviour by governments, private sector, households and individuals, including efforts to ameliorate environmental conditions.

To the three PSR elements can be added:

- **Effects** on the ecosystem, human health and human welfare.

Through the PSR framework, four relevant questions can be answered:

- What is happening in the environment? (state)
- Why is it significant? (effects)
- Why is it happening? (pressure)
- What are we doing about it? (societal response)

Other words can be chosen to convey indicator characteristics: compliance, diagnostic (cause-effect), early warning, progress, administrative, ambient, trend. The words themselves are not important. The linkage between policy decisions, which lead to program actions, which lead to changes in ecosystem stress, which lead to desired environmental outcomes, is important, as are the availability of indicators to measure each of these.

CRITERIA FOR INDICATOR SELECTION

What criteria should be used to establish a list of indicators based on the Agreement's and the Commission's policy needs? Common sense dictates that indicators be measurable with available technology and at a reasonable cost; scientifically objective, reliable, and valid for assessing or documenting ecosystem quality; timely; easy to understand; and useful for providing information for management decisionmaking. Numerous lists of selection criteria have been formally developed, for example:

- The Commission's Council of Great Lakes Research Managers identified criteria for ecosystem health indicators.

- Eyles and Cole proposed two sets of indicator selection criteria -- science based and use based -- with the caveat that all indicators should be goal directed. They also indicated that good indicator selection is dependent upon specifying the problem to be measured or managed.

- The Environmental Indicators Task Group of the ITFM organized selection criteria into three groupings: scientific validity (technical considerations), practical considerations and programmatic considerations.

The indicator selection criteria for these three sources are described and summarized in Appendix C. For its purposes, the Task Force perceived that selection criteria fall into three broad categories: criteria reflecting the substance of the Agreement itself, scientific completeness, and public understandability. To a large extent, the Task Force has also incorporated the criteria identified by the Council, Eyles and Cole, ITFM, as well as others. Clearly, no one indicator will meet all the criteria, but collectively a suite of indicators will broadly meet the requirements.

Criteria for the Great Lakes Water Quality Agreement

The Commission is called upon to assess progress both in the state of the Great Lakes and in programs to protect and remediate their integrity. Among the targets, programs and measures called for in the Agreement are those enumerated in Table 1.

Criteria for Scientific Completeness

An assessment of what set of indicators would be necessary and sufficient scientifically to assess progress is needed,

and was one subject of the Task Force's October 5-6, 1994 workshop. This can result in a very long list of indicators, however, due to the extensive and detailed knowledge and specialization of experts, as was demonstrated at the workshop. It is necessary to reduce the number of indicators using judgment and broad knowledge of ecosystem functioning. To identify appropriate indicators from a scientific perspective, the criteria given in Table 2 should be considered.

Criteria for Public Understandability

Finally, because of the function of indicators as a public information and policy tool, it is important that a set of criteria be established that tests for the ready understandability of the indicator by senior policymakers and the public, and for the relevance of the indicator to actual policy decisionmaking and related policy levers. It may also be important for these indicators, if they are to be kept few in number, to have a high integrative capacity, *i.e.* to give information about a wide spectrum of concerns. Of course, this results in a trade-off with specificity, accuracy and precision that is important in the scientific realm.

INDICATORS AS MEASURES OF COMPLEX SYSTEMS

As defined above, indicators are measurements or statistics that represent something more than just the variable itself. They are surrogates for a plethora of more detailed statistics which allow one to monitor in a simple way the overall condition of a much more complex system. The problem with the notion of system is that there are no hard and fast natural boundaries. There are many well developed and well accepted indicators of human social development or of the human economy, each of which is considered to be a separate self-contained system. There is a growing collection of indicators of environmental conditions and even of indicators of ecological health for natural ecological systems, again considered as separate systems. More recently it has been recognized that the human economy and human social systems are embedded in, and dependent on the natural environment and that the latter in turn is impacted by the human sub-systems.

What is really needed is a set of indicators that encompasses the whole ecosystem, rather than just separate components. These indicators must focus on the sustainability of the whole system or, in terms of the development of the human sub-system, indicators of sustainable development. Once such sustainable development indicators are developed, they could provide solid bases for decisionmaking at all levels (local, regional, national and international) and contribute to a self-regulating sustainability of integrated environmental and development systems. While some progress is being made in this direction, such a comprehensive set of indicators is not yet available to policymakers.

INDICATORS AND DESIRED OUTCOMES

Desired outcomes for the Great Lakes basin ecosystem can be characterized by appropriately selected indicators. The concept of desired outcomes is introduced in Chapter 4, and specific desired outcomes, plus indicators and measurements for each, are detailed in Chapter 5. That discussion includes consideration of suites of indicators (local and regional) to address questions of spatial and geographic scale.

INDICATORS AND ECOSYSTEM OBJECTIVES

The Agreement contains a number of indicators, specifically:

- Specific water quality objectives (Annex 1)
- Lake ecosystem objectives (Supplement to Annex 1, quantified in Annex 11 as ecosystem health indicators).

Through the Lakewide Management Plan (LAMP) process, other ecosystem objectives are being developed; a number have been proposed for Lakes Ontario, Michigan and Superior. The Commission's Council of Great Lakes Research Managers published *A Proposed Framework for Developing Indicators of Ecosystem Health in the Great Lakes Region.* That report is serving as a model for the LAMP process for identifying ecosystem objectives and indicators of progress toward those objectives. In addition, the Commission developed quantitative targets to denote achievement of restoration of the 14 beneficial uses presented in Annex 2.

The Task Force believes that its work is consistent with these activities. The indicators it has identified will help evaluate Agreement progress toward specific desired outcomes. Each indicator should have a quantifiable end point. The Task Force pondered whether to quantify end points for each desired outcome, *i.e.* measurable targets or goals to tell us when we have arrived. Quantification of indicators and their end points is, in the Task Force's view, an appropriate consultative activity of stakeholders -- the Parties, environmental nongovernment organizations, industry, among others -- perhaps under the auspices of the Commission and its boards.

Table 1. SELECTED TARGETS, PROGRAMS AND MEASURES IN THE AGREEMENT

- Achievement of General and Specific Objectives
- Effective standards and other regulatory requirements to achieve them
- Research on identified needs and other priorities
- Mechanisms for international organization
- Control of pollution sources including:
  - Municipal sources (pretreatment, sanitary, storm and combined sewer overflows)
  - Industrial sources (waste treatment and control, substantial elimination of persistent toxics, nutrient, thermal and nuclear inputs)
  - Nonpoint sources (pesticides, animals, land-use planning)
  - Shipping activity (spill prevention, surveillance, contingency plans)
- Airborne source identification
- Additional programs given specifically in the annexes, notably:
  - Remedial Action Plans, Lakewide Management Plans, and Point Source Impact Zones
  - Virtual elimination and zero discharge of persistent toxic substances
  - Dredging
  - Groundwater
  - Wetlands

Table 2. CRITERIA FOR SCIENTIFIC COMPLETENESS

- Is the indicator necessary to characterize the desired outcome properly and to evaluate progress?
- Is the indicator relevant, *i.e.* important and of value?
- Is the indicator scientifically valid?
- Are historical data and information available to define trends and possibly acceptable and unacceptable conditions, and can measurements be made currently and in the future?
- Can the data and information be interpreted in terms of the desired outcome?
- Can reference or target values be established?
- What are the costs to acquire the data and information, including availability of human and financial resources?
- What is the quality of the data and information, and can confidence be placed in them?
- Is the indicator sensitive, *i.e.* without an all-or-none response or extreme natural variability?
- Is the indicator timely, *i.e.* providing data and information quickly enough to initiate effective action?
- Is the indicator anticipatory, *i.e.* capable of providing early warning, an indication of change before serious harm has occurred?
- Is the indicator integrative, *i.e.* possessing the capacity to combine a variety of diverse data and information?
- Is the indicator broadly applicable, *e.g.* to more than one desired outcome?
- Is the suite of identified indicators sufficient to fully characterize the desired outcome and to evaluate Agreement progress?

CHAPTER 3

ORGANIZING PRINCIPLES AND METHODOLOGY

To fulfill its mandate, the Task Force sought indicators that described phenomena. The goals of that description were to explain "the Great Lakes ecosystem" and to better understand causation. Useful predictive indicators are required for well-informed ecosystem management and to attain the Agreement purpose of ecosystem integrity.

CONCEPT OF ECOSYSTEM TYPE AND SCALE

Ecology is the study of the interrelationships of biota, among themselves and with their surroundings. Ecosystems are units of ecology comprised of living and non-living components. We "see" an ecosystem through certain observables or indicators. Anything representative of the state of the biota or of biota/environ relationships can be used as an indicator in an ecosystem approach such as that called for in the Agreement. Denizens of an ecosystem reveal themselves. Any particular moment of awareness provides the subject matter of ecology.

In the largest scale ecosystem (the ecosphere), everything is connected to everything else. Ecosystems are not free-and-independent parts of the ecosphere. They always exist in a context that includes both the ecosystem and its relationship to a larg system of the ecosphere. An ecosystem is only a convenient figment of human conception and/or perception.

Consideration of scale and choice of what type of ecosystem is most representative of the Great Lakes is crucial in the selection of indicators. Scale pertains to size in both space and time. Since size is a matter of measurement, scale depends on the measurement scheme chosen. For instance, something is large scale if it requires observations over relatively long periods of time or large areas, or both. In addition, the scale used to perceive an ecosystem will determine the size of that ecosystem, that is, different scales will make the ecosystem appear in different ways. When a particular scale is chosen for observation, only certain things are seen; when the scale is changed, what is seen also changes, although the system under study has not. On the other hand, conceptual devices such as community and organism are independent of scale.

Material ecological systems, such as "the Great Lakes basin ecosystem," are scale dependent. Such systems can be studied in many ways, regardless of scale. The conceptual devices chosen embody a particular set of relationships. As noted above, relationships are the principal subject matter of ecology.

Ecosystems can be viewed as multidimensional, consisting of the three spatial dimensions and time; this is also called the spatiotemporal scale. Variables, or quantities that can change (such as temperature and wind speed) can be described in spatiotemporal terms. For each variable, indicators or measurements can be selected, applied and interpreted. Indicators and measurements depend on the perspective selected. Considerations of scale

and type provide particular context for such terms as ecosystem, integrity, comprehensiveness, biodiversity. They lend utility to the indicators and measurements presented for each desired outcome in Chapter 5.

The Task Force used the organizing principle of "hierarchy" to understand the constraining relationship between systems at higher and lower levels of spatiotemporal scale. In hierarchical perception, an adequate understanding of an ecosystem requires consideration of at least three levels at once: the level in question; the level above, which gives context, role, and/or significance; and the level below, which gives mechanisms. Accordingly, when the Task Force recommends an indicator (*e.g.* for "the Lake Superior basin ecosystem"), it implies the need to also develop an indicator for the level above (the "Great Lakes basin ecosystem") and the level below (basins of smaller spatiotemporal scale).

The Task Force restricted itself to identifying what might be called middle level evaluative indicators, recognizing that they are embedded in a hierarchy.

An indicator for an ecosystem on a scale less than the ecosphere does not establish any real boundaries between components in the fully connected ecosphere. Ecosystem boundaries depend on human perceptions and conceptions; these must be acknowledged to have meaningful discussion about any particular ecosystem. A better understanding of "the Great Lakes basin ecosystem" requires clarification of and agreement about the type and the scale of that system and the bounds placed on it.

Those bounds can change, as our understanding changes. For instance, the 1972 Agreement referred to "the Great Lakes System"; in 1978, the concept was expanded to "the Great Lakes Basin Ecosystem." A basin or watershed is a concept of hydrology or process-function ecology. Other types of ecology (discussed below) can also be used to characterize this ecosystem. The Great Lakes ecosystem is a subsystem of the ecosphere; the fact that it may be viewed as a basin is necessary but not sufficient. Ecomanagement demands use of a spectrum of ecological conceptions and perceptions. Asserting that an indicator is "ecologically based" does not ensure that it derives from an ecosystem approach. Indicator selection must be driven by mutually understood ecosystem definitions.

Because system definition depends on the scale of integration, it is necessary to identify the scale of the ecosystem from various perspectives. When scales of integration from different perspectives coincide, special attention can be given to measuring at those scales. These scales tend to coincide with tangibles (*e.g.* watersheds), which form natural targets for measuring or monitoring strategies.

Preserving the integrity of watershed subsystems may be crucial to preserving the entire ecosystem's integrity when viewed from a variety of perspectives. Ecosystem integrity is holistic; it applies to the entire integrated system and not just one or more of its components.

Since the Great Lakes ecosystem can be conceived and perceived from a variety of perspectives, it is not just one ecosystem. There is no generic "Great Lakes ecosystem." Each perspective bounds the system in terms of observation criteria for the type and scale (temporal and spatial) of the system. It is imperative that the ways of conceiving and perceiving the Great Lakes ecosystem be clearly understood and communicated. Otherwise, stakeholders may misconstrue the type and scale of the system under consideration.

Thus, the Great Lakes ecosystem exists in a context. That context is constant in the relationship between the Great Lakes ecosystem and its environment. Ecosystem health and integrity is the assurance of intact process pathways within the living system and between it and its environs.

Each desired outcome (see Chapter 5) must be characterized by indicators that are identified as to type and scale. It is impossible to say what is a disturbance or stress without specifying the scale and organizational level or type of ecosystem. Indicators which prove representative at one scale may have little utility at another scale.

Clearly, the Task Force cannot address all aspects of conceptual, real and abstracted relationships in the human environment, nor can the Task Force utilize all the possibly meaningful indicators in the ecosphere or even in the abstracted portion of it known as "the Great Lakes ecosystem." It has selected a limited set on which to focus attention. Further, given the dynamism of the human environment, any indicator chosen as most useful today may not be that useful tomorrow. However, choosing a different indicator poses problems that arise from breaking a chain of useful points for comparative measurements.

ECOLOGICAL PERSPECTIVES

In identifying indicators, the Task Force considered the Great Lakes ecosystem at several scales (*e.g.* Areas of Concern, lakewide, basinwide), from four criteria for ecological observation: community ecology, process-function ecology, landscape ecology, and population ecology. These ecological "windows" or types can be used as organizational frameworks in order to gain a better understanding of the Great Lakes ecosystem at any spatiotemporal scale.

To devise a conceptual framework for evaluative indicators, more than one type of ecology should be utilized. This report largely reflects these four ecological windows. All are science-based and conceptually user-friendly. In defining a particular type of Great Lakes ecosystem, each provides a conceptual interface that can be appreciated by scientist and layperson alike. Each is a way of abstracting, from the global ecosphere, a Great Lakes ecosystem whose indicators enfranchise a wide audience of stakeholders and can prove useful in governance and in further learning.

A more complete strategy of indicator development would include indicators from at least one more ecosystem type: organism. There are individual organisms that are unique and important in their own right as ecosystems, as well as being important components in the other types of ecosystems. The Task Force opted, however, to deal more at the population level.

Community Ecology

In community ecology, organisms from different species show indicative behaviour of interest because of the accommodation they have made for each other. A community is composed of organisms assigned through taxonomic identification. The community as an ecosystem, particularly at the scale of the whole Great Lakes ecosystem, is a complex notion, which can mean different things for different taxonomic and resource-sharing groups. The parts of the community must accommodate each other; otherwise the community is only an arbitrary collection. At any instant the community is the embodiment of prior processes of accommodation, which enable coexistence as community members. There is a distinctly temporal component to communities that extends beyond the place, itself, at a moment in time. The past processes that built a community (*e.g.* the receding of the waterline, leaving a wetland community at Lake Erie's margin) have become part of community structure.

Applied community ecology is one way to acknowledge the linkages of the community known as the "Great Lakes ecosystem," incorporating the concerns of human health, socio-economic infrastructure, and ideological values (ethics) that underlie the Agreement.

Process-Function Ecology

In process-function ecology, matter/energy and information essential to the Great Lakes ecosystem are studied, to understand exchanges between living systems and their environment. Process-function can be viewed as a sequence of events; parts and explanatory principles are process pathways and fluxes between organisms and their environs. The critical parts are the pathways, not the organisms themselves. The functional parts are the pathways in which the organisms are subsumed.

To view process-function ecosystems requires invocation of conservation and principles of mass balance. Process-function ecosystems are not readily defined by spatial criteria such as area. They are more easily conceived as a set of interlinked processes that may be diffuse in space but easily defined in turnover times. Processes pertaining to very differently scaled areas encounter each other in the process-function ecosystem. As an example, with the atmosphere as part of the process-function ecosystem, the spatial boundaries of the ecosystem move every time a new weather system passes through the region. Entire process-function ecosystems vary in size, not by area but by the scale of the pathways that comprise them. The size of a process-function ecosystem is the largest extent that only just contains the definitive pathways of the system. Similarly, processes only operate over certain time spans, after which they need to be respecified if they are to predict ecosystem function.

Landscape Ecology

In landscape ecology, assemblages of ecosystems occurring in a geographically defined region (a landscape) are dealt with. The basic spatial unit is the site, a small section of the earth's surface. A site is embedded in a site cluster. A site cluster is embedded in a landscape (or waterscape). Each landscape is embedded in a land/water system. A land/water system is embedded in a region, which in turn may be embedded in a continental land mass. According to this concept, most watersheds or basins are within a landscape, and some large watersheds (*e.g.* the Great Lakes basin ecosystem) include several landscapes and waterscapes.

Since landscapes are the most tangible of the ecological criteria (types), they tend to be studied at conveniently human scales. There are very small and very large scales at which landscape ecosystems can be profitably studied.

Landscape ecosystems can be related to other ecological criteria for organization, such that the landscape becomes the spatial matrix in which organisms, populations and process-function ecosystems are set. Landscape ecosystems are, however, meaningful in their own right. It is useful in situations such as the Great Lakes ecosystem, which contains whole lake ecosystems as well as local Areas of Concern that can be viewed as ecosystems, to consider differently scaled systems while using only the landscape criterion.

Applied landscape ecology systematically and comprehensively bounds the surface watershed known as the Great Lakes basin ecosystem, defined in the Agreement through both watershed (drainage basin of the St. Lawrence River) and geopolitical (upstream from the point at which this river becomes the international boundary between Canada and the United States) considerations. The catchment of each of the Great Lakes may be considered a landscape (waterscape), and each Area of Concern may be considered a site cluster or site.

Population Ecology

In population ecology, two organizing principles give two types of populations: spatial congruity, in which population members are aggregated; and a shared history of some sort (this need not be genetic). The strategy for dealing with populations comes from their being composed of only one sort of entity, usually individuals from the same species. Populations have a homogeneity of scale in their attributes. Members of a population all belong to one spatially and temporally defined level.

Population generally refers to a temporal cross-section -- an instant in time. Population is also perceived to have a spatial limit; members occupy the landscape all at the same scale. Populations can be seen nested inside bigger populations.

Populations and communities both contain individuals. The single-species characterization of populations as opposed to the multispecies characterization of communities leads to different sorts of occupancy of landscapes.

ECOSYSTEM FRAMEWORK

A conceptual framework should link environment-related data to policy and management needs, identify duplication and gaps in existing information collection efforts, and provide an impetus to develop new data and indicators to fill gaps. Several factors underlie the need for a unifying framework. Information collection, analysis and interpretation are linked to environmental decisionmaking processes at several levels. For instance, information generation and use is driven by the statutory and regulatory framework (*e.g.* policy goals). At another level, environmental assessment and management are influenced by philosophies that shape visions of human-nature relationships, and by the scientific models used in environmental research and assessment. These paradigms and models shape the perception of problems and how people evaluate evidence, at least in part because they predispose people to ask different sets of questions.

Ideally, the legal/regulatory framework and the paradigms that influence decisionmaking should be compatible with the scientific ones used in environmental research and assessment. A conceptual framework should integrate the scientific, legal/regulatory and philosophical paradigms that underlie information generation and use. Thus, a framework should do more than codify a collection of policy goals, and the resulting information system should be more than the agglomeration of databases from existing monitoring programs.

To form the basis for a unifying framework, principles and methods of ecological science should be applied to analyze and manage human-environment interactions. The conceptual framework should consist of hierarchical sets of environmental values, goals and priorities for ecosystems defined at various spatiotemporal scales, with sustainability of human activities as an explicit goal or constant. Such a framework must be anticipatory, focusing on long-term and emerging environmental issues as well as more immediate regulatory concerns, in keeping with the concept of sustainability.

THE ECOSYSTEMIC APPROACH

Ecosystemic approaches deal with space-time (spatiotemporal) relationships. The "ecosystem approach" committed to in the 1978 Agreement can be described as systematic and comprehensive. In this context, comprehensive in space and time means that the approach covers all the significant kinds of interactions present in the system. A comprehensive ecosystemic approach addresses a set of consciously chosen indicators that reveal a full set of representative characteristics of that system's parts, as well as the emergent properties of that system as a whole. It entails looking at the Great Lakes ecosystem in several ecological ways, each of which generates a certain type of indicator and, within that type, data/information that is scale-dependent.

Considerable wherewithal has been devoted to gaining a better understanding of the Great Lakes ecosystem and clarifying the ecosystem approach of the Agreement. An ecosystemic approach consists of eight essentials:

1. Acknowledgement that ecosystems are life/environs systems couched in distinctly human terms; ecosystems are types of systems bounded by the use -- in scientific ecology -- of such different observational "criteria" as landscape, community, organism, process-function and population. Criteria are the basis upon which one makes a decision as to what life/environs relationships are important. Together,

context and content generate significant indicators at each scale-defined level.

2. Recognition that each type of ecology, whether or not it is scientific, identifies ecosystems entailing many spatiotemporal scales of structures and processes. Effective communication about an ecosystem must specify, at the outset, what scale is of interest and concern. Structures (*e.g.* a wetland community in an Area of Concern; a watershed) that match human scales of unaided perception are the most well known.

3. A cohesive intellectual framework for applied ecology that includes humans and their adaptive, associative and ideological activities in each type of ecosystem. This applied ecology is not value-free but is predicated on some world view (*e.g.* the view espoused in the Ecosystem Charter for the Great Lakes-St. Lawrence Basin) which must be made known to stakeholders in the planning process if they are to have a chance of developing a better understanding of the subject system.

4. Use of ecological (but not necessarily natural) boundaries to define spatiotemporal planning, assessment and management units.

5. Systematic investigation of pertinent ecosystem types, using systems analysis. Analyses of the Great Lakes ecosystem qualify as systems analyses and are systematic in that sense of the word. Also, the nearly numberless topics of the Great Lakes ecosystem have been abstracted to a lesser number via various systematic disciplines of investigation. Among these, the disciplines of science (and their interdisciplinary endeavours) offer systematic ways of paring volumes of data and information to manageable numbers that are useful for both the scientists and laypersons who seek to understand better the state of the Great Lakes ecosystem.

6. Comprehensive characterization of the kinds of relationships that are essential to ensure the integrity of the system's parts and of its emergent properties as a whole integrated set.

7. Use of adaptive management strategies, based on feedback/feedforward from new information, to improve policy and management under conditions of uncertainty.

8. Enfranchising interested and/or affected entities (stakeholders in the widest sense) to the degree possible in planning and decisionmaking which affect the subject ecosystem.

A systematic approach has the characteristics of good systems analysis. Among these characteristics are: the use of analysis methods that fit the character of the problem and the nature of the available data, while treating all data skeptically; the use of criteria with sensitivity and caution, giving weight to qualitative as well as quantitative factors; honesty in the labelling of assumptions, values, uncertainties, hypotheses and conjectures; and awareness of partial analysis and the limits of analysis generally. The whole process of systems analysis should demonstrate understanding. The task is not merely to indicate the "best" solution, but also to develop a range of alternatives recognizing that, in living systems, problems are never truly "solved" once-and-for-all-time.

The Task Force utilized methodologies consistent with a systematic, comprehensive ecosystemic approach to analysis. In choosing indicators, the Task Force considered ecosystem type and spatiotemporal scale of interest within that ecosystem type. This required attention to context. The selection of indicators may be somewhat arbitrary but is not capricious. The Task Force chose to use the methods of community ecology, landscape ecology, process-function ecology and population ecology, as discussed above, in developing suites of indicators that may not be comprehensive in detail but are comprehensive in scope. Each is useful in linking existing environment-related data to policy and management needs. Together these different criteria for ecological observation enable one to get a better handle on what is known, what is not known, what could be known, and what should be known as we use our many windows to view the Great Lakes ecosystem.

CHAPTER 4

FRAMEWORK FOR EVALUATION OF AGREEMENT PROGRESS

In today's society, we have a surfeit of data and information, but the question remains, what do all these data and information mean? How do we respond to the questions: Are the Great Lakes getting better? Have we achieved fishable, swimmable and drinkable conditions in them? This chapter provides a context or framework within which data and information can be used, so we can begin to answer these most fundamental questions.

The framework incorporates the PSR (pressure-state-response) model discussed in Chapter 2. It consists of five components: the Agreement purpose, desired outcomes, relevant data and information, stresses, and programs and policy. These are linked, as shown in Figure 1. In applying the framework, assumptions are made about stresses, measurements and indicators, and programs and policies are implemented accordingly. If a desired outcome is not achieved, the feedback loop urges that programs and policies are revisited and revised accordingly to ameliorate the stress. To achieve desired outcomes and ecosystem integrity, the process must be iterative.

Not depicted, but clearly a component of the framework, is the concept of time. The rate of progress toward and achievement of the desired outcome must be seen in the context of time, presumably the faster the better.

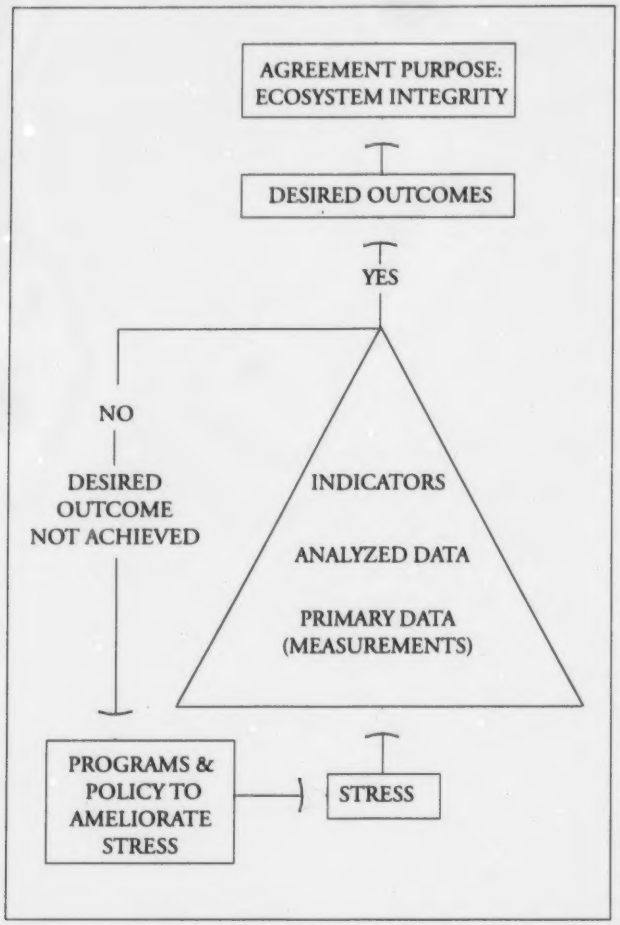
Framework components are discussed below. In its deliberations, the Task Force identified one stumbling block with regard to evaluation of Agreement progress: the need to clearly articulate desired outcomes or ecosystem goals. Accordingly, the Task Force hopes to help bridge this gap. Stresses are also discussed, since desired outcomes can be achieved through mitigation of stress.

ECOSYSTEM INTEGRITY

An ecosystem can be described by function (*e.g.* energy flow, nutrient cycling) or by structure (living and non-living components: physical, chemical and biological, including humans), or both. An ecosystem can also be described at various geographic scales (*e.g.* local Areas of Concern, watersheds, individual lake basins, basinwide and beyond). In its deliberations, the Task Force incorporated measures of both functional and structural integrity as well as differences in scale.

The purpose of the Parties in formulating the Great Lakes Water Quality Agreement "is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." The Agreement defines "impairment of beneficial uses" as "a change in the chemical, physical or biological integrity of the Great Lakes system sufficient to cause" any of the 14 specific impairments listed in Annex 2 of the Agreement.

Figure 1. FRAMEWORK TO EVALUATE AGREEMENT PROGRESS



Ecosystem integrity encompasses three major factors:

- The ability to maintain normal operations under normal conditions, *i.e.* ecosystem health.
- The ability of the ecosystem to cope with exogenous change, *i.e.* stress.
- The ability to continue the dynamic process of self-organization on an ongoing basis, *i.e.* to continue to evolve, develop and proceed with the cycle of birth, growth, death and renewal.

Ecosystem integrity can be interpreted in terms of the viability of the natural system and human uses of that system. Indeed, human uses and human values, which are essential components of ecosystem integrity, have been, and will continue to tremendously influence the viability of the natural system and, hence, overall ecosystem integrity. Human uses and values include:

- Sustainable economic activity, such as industrial and agricultural production, commercial fishery, recreation, navigation and commerce.
- Human health, as reflected in the terms fishable, swimmable and drinkable.
- Measures of individual or societal welfare, such as the quality of life and cultural concerns.

Human aspirations, expressed in economic, social and cultural dimensions must be achieved, along with natural realities, in order to ensure long-term ecosystem integrity. Such components must be measured for signs of progress toward desired outcomes. Thus, our strong desire to maintain human uses and values must be tempered to ensure the viability and balance of the natural system. The challenge is to achieve that optimal or desired balance point among these needs.

A.W. King, in *Ecological Integrity and the Management of Ecosystems*, notes that changes in a system defined by one set of criteria

"may have little impact on observations of that same system defined by other criteria. ... Translating ecosystem integrity defined from one perspective to notions of integrity for another can be problematic. Assessment of ecosystem integrity is strongly dependent upon the perspective from which observations are organized. Definitions and measures of ecosystem integrity from one perspective may complement, contradict, or be largely independent of those from other perspectives. Care must therefore be taken to define the perspective used in making statements about ecosystem integrity and in making inferences about integrity from other perspectives. The strongest inference can be made by explicitly examining the integrity of alternative, complementary descriptions of an ecosystem. ... Those [indicators of ecosystem integrity] associated with human value judgements, like economics or aesthetics, should not be excluded by a prejudice for natural, ecological, or scientific perspectives."

DESIRED OUTCOMES

Ecosystem integrity, including pertinent human uses and values, can be expressed in terms of desired, positive outcomes to which the public and decisionmakers can relate and strive to achieve. Desired outcomes are implicit in the Agreement. The Agreement's 14 beneficial use impairments can be viewed as surrogate descriptions (see Table 3) and thereby provided a touchstone for the Task Force's investigation. The beneficial use impairments can

Table 3. IMPAIRMENTS TO BENEFICIAL USES FOR THE GREAT LAKES [a]

The Great Lakes shall be free of the following as a result of human activities in the basin:

(i) Restrictions on its fish and wildlife consumption because of health concerns.
(ii) Tainting of fish and wildlife flavour.
(iii) Net degradation of its fish and wildlife populations.
(iv) Fish tumour or other deformities above predetermined background levels.
(v) Bird, animal or other biota deformities or reproduction problems above predetermined background levels.
(vi) Net degradation of benthos.
(vii) Restrictions on dredging activities because of contaminant levels in sediment.
(viii) Cultural eutrophication or undesirable algae.
(ix) Restrictions on drinking water consumption, or taste and odour problems.
(x) Beach closings.
(xi) Degradation of aesthetics.
(xii) Added costs to agriculture or industry.
(xiii) Degradation of phytoplankton and zooplankton populations.
(xiv) Net loss of fish and wildlife habitat.

[a] Based largely on beneficial use impairments given in Annex 2 of the Agreement. The International Joint Commission has published guidelines to establish when each impairment has been eliminated, thus the use met and ecosystem integrity achieved.

be succinctly organized into a series of desired outcomes that relate to the chemical, physical and biological integrity of the natural system, including human uses and values, that is, in terms of human, ecosystem, economic and societal health. The Task Force presents the following nine desired outcomes, synthesized from deliberations at the Indicators Workshop (held October 5-6, 1994) and subsequent Task Force discussions:

1. Fishability
2. Swimmability
3. Drinkability
4. Healthy Human Populations
5. Economic Viability
6. Biological Community Integrity and Diversity
7. Virtual Elimination of Inputs of Persistent Toxic Substances
8. Absence of Excess Phosphorus
9. Physical Environment Integrity.

Collectively, this suite of nine interrelated desired outcomes provides a reasonable initial perspective of ecosystem integrity for which indicators can be selected to evaluate Agreement progress. The Task Force provides (Table 4) a narrative description for each outcome incorporating the Agreement's beneficial use impairments. The intent of these desired outcomes is to restore uses rather than just protect resources.

These desired outcomes are applicable not only to the Great Lakes basin ecosystem as a whole but to any geographic area, such as an Area of Concern, a lake basin, or an area outside the basin. The Task Force has provided only nine it believes are necessary, but these may not be sufficient to characterize fully ecosystem integrity. Other outcomes may also need to be identified.

What exactly do these nine desired outcomes mean? Terms such as fishable, swimmable and drinkable are subjective, qualitative and possibly vague. This leads to confusion and disagreement. For example, if the desired outcome is to achieve a "healthy aquatic community" or "aquatic ecosystem health," does it envisage a self-sustaining native fishery or an artificially supported put-and-take fishery?

Information provides the basis for gauging progress and decisionmaking, but accountability is possible only if goals and measures of progress are explicitly stated. Therefore, desired outcomes must be clear and unequivocal. The greatest impediment to implementing effective monitoring and system protection is lack of agreement on management goals, *i.e.* definition of desired outcomes, especially in a multi-use system such as the Great Lakes. Choice of a desired outcome is setting a public value that is perceived as important. Therefore, it is important to develop and

Table 4. DESIRED OUTCOMES FOR THE GREAT LAKES BASIN ECOSYSTEM

1. **Fishability.** There shall be no restrictions on the human consumption of fish in the waters of the Great Lakes basin ecosystem as a result of anthropogenic (human) inputs of persistent toxic substances.

2. **Swimmability.** No public bathing beaches closed as a result of human activities or, conversely, all beaches are open and available for public swimming.

3. **Drinkability.** Treated drinking water is safe for human consumption; human activities do not result in application of consumption restrictions.

4. **Healthy Human Populations.** Human populations in the Great Lakes basin are healthy and free from acute illness associated with locally high levels of contaminants, or chronic illness associated with long-term exposure to low levels of contaminants.

5. **Economic Viability.** A regional economy that is viable, sustainable and provides adequate sustenance and dignity for the human population of the basin.

6. **Biological Community Integrity and Diversity.** Maintenance of the ability of biological communities to function normally in the absence of severe environmental stress (ecosystem health) and to cope with changes in environmental conditions which impose stress, *i.e.* to be able to maintain their processes of self-organization on an ongoing basis (ecological integrity). Maintenance of the diversity of biological communities, species and genetic variation within species.

7. **Virtual Elimination of Inputs of Persistent Toxic Substances.** Virtual elimination of inputs of persistent toxic substances to the Great Lakes system.

8. **Absence of Excess Phosphorus.** Absence of excess phosphorus entering the water as a result of human activity.

9. **Physical Environment Integrity.** Land development and use compatible with maintaining aquatic habitat of a quantity and quality necessary and sufficient to sustain an endemic assemblage of fish and wildlife populations.

agree on an explicit definition of each desired outcome -- or ecosystem goal -- for the Great Lakes, accompanied by a strong rationale explaining why each was selected.

As noted above, Table 4 provides a brief narrative description for each of the nine desired outcomes. Each also requires more specific characterization in terms that describe ecological characteristics for the desired outcome, and fully take into account human values.

The Task Force believes that identification, definition and characterization of desired outcomes are the responsibility of the Parties, in close consultation with stakeholders and with the advice of scientists and others with appropriate technical expertise and understanding of ecosystem components and functioning. To advance the issue, the Task Force not only proffers the nine desired outcomes listed above, it also provides advice and guidance in the form of detailed characterizations, presented in Chapter 5. The Parties, in consultation with stakeholders, can select, refine and adopt a necessary and sufficient suite of appropriately defined and characterized desired outcomes.

Desired outcomes are clearly interrelated. One could group the nine in terms of ecological and human health, societal uses and human welfare, and pressures on the environment. One could also order the outcomes to reflect the observation that natural ecosystem components (such as absence of excess phosphorus) are the basis of those that focus on human uses. Such grouping and ordering may help the reader visualize and more easily achieve the Agreement goal of ecosystem integrity.

The Task Force observed that certain beneficial uses can be attained without reaching ecological or biological integrity, *e.g.* a put-and-take fishery could achieve a beneficial use but not ecological integrity. This is a consequence of beneficial uses being based on human welfare and socio-economic needs rather than ecological conditions. Although it is tempting to lean toward beneficial uses as the measurable desired outcome, the ultimate Agreement goal is the physical, chemical and biological integrity of the waters of the Great Lakes basin ecosystem.

ECOSYSTEM DYNAMICISM

In formulating desired outcomes, we must recognize that ecosystems are not static -- they are dynamic and the balance is constantly changing. Thus, desired outcomes need to be continually refined. The structural and functional properties of ecosystems change over time because of natural ecological succession and other factors such as long-term shifts in climate and hydrology, as well as the impact of intrinsic human values. Consequently, it is unrealistic to think that we can restore a lake precisely to the ecological state it was in before a stress occurred, or to

the unknown (and unknowable) state to which it would have evolved in the absence of a stress.

Clear definition and articulation of a desired outcome requires difficult choices, in particular, value-laden selection criteria for determining which changes are desirable and which are not. Consideration of long-term costs and benefits for the Great Lakes influences the selection and definition of desired outcomes and measurable end points. The success of programs and other measures undertaken to achieve a desired outcome must be evaluated according to the extent to which human-oriented goals (fishable, swimmable, drinkable) are met. Success must also be evaluated in terms of ecological criteria which, hopefully, are not in conflict with human-centred goals for ecological sub-systems.

Ecosystems can respond to changes (*i.e.* stress) in five qualitatively different ways:

1. Continued operation as before, even though operations may be initially and temporarily unsettled.
2. Operation at a different level but using the same original structure (*e.g.* a change in the total numbers for different species).
3. Emergence of new structures that augment or replace existing structures (*e.g.* new species or paths in the food web).
4. Emergence of a new ecosystem made up of quite different structures.
5. Complete ecosystem collapse with no regeneration.

There is no scientific basis to conclude that an existing ecosystem is the only one to have integrity. The reorganized ecosystems noted above may be just as healthy as a prior ecosystem, though they may be different.

An ecosystem has no inherent preferred state for which it should be managed, although humans tend to ascribe such desired states to nature. To accept only temporary change denies the fundamental dynamic nature of ecosystems, and can lead to disastrous mismanagement. We must also recognize that management goals that involve maintaining some fixed state in an ecosystem or maximizing some function (*e.g.* biomass, productivity, number of species, economic productivity) or minimizing others (*e.g.* pest outbreak) can also lead to disaster, no matter how well meaning those management goals *per se*.

Ecosystems represent a balance, an optimum point of operation, and the balance is constantly changing to suit a changing environment. Management must recognize that some changes in ecosystems are undesirable, because they represent a loss of integrity. The intent is to promote a self-sustaining, stable system that reflects agreed-upon, desired outcomes -- a robust system that is able to resist stress and resilient to rebound once a stress has been removed. The most robust ecosystems are generally the most dynamic, with internal feedback and compensating mechanisms. The best working ecosystems are the most complex.

One challenge is to reach understanding and agreement on what is an acceptable preferred state of the ecosystem, considering both natural and human factors. Society must ensure that deliberate actions to maintain the system in a condition that serves its purposes do not push the system in a direction that leads to a catastrophic flip into an undesirable condition. The system society chooses to manage for must be characterized by sufficient restoring forces within its own self-organization capabilities. And, if society chooses to manage toward a particular outcome, it must question how sustainable are its practices in the face of the inevitable tendency of the system to move toward some condition of its own choosing. Is society driving the system toward collapse into another regime? There is no "right answer" in establishing policy goals over the long term; at best, society can only suggest directions or temporary targets based on science, risk assessment, public opinion, equity and other decision tools.

A highly managed ecosystem may be healthy but not well. As a human analogy, a diabetic is not well but, with insulin, is managed and healthy. A self-sustaining ecosystem is both well and healthy. The Task Force assumed a policy of minimal ecosystem management.

DATA AND INFORMATION

Associated with each desired outcome is a body of relevant data and information. They can reflect absolute values, rates of change, ratios, quantitative assessments or other considerations. They should be technically and scientifically based but also understandable and relevant. Indicators provide a framework for collecting and reporting information. Today's electronic technology should facilitate identification and access of data sources and assembly of information. Questions remain, however. Which data should be compiled, and how does one massage a mass of facts into a handful of meaningful numbers that signal whether environmental problems are getting better or worse? To do this, one must understand how indicators are quantified and constructed and what they really mean. Once accepted, they can then be used to evaluate progress, reach conclusions, and make decisions about desired changes.

As depicted earlier, a pyramidal shape (suggested at the Indicators Workshop) is used to convey the hierarchical nature of data and information as well as their integration, in order to provide relevance to the particular desired

outcome. Data and information fall into three broad categories (see Figure 1).

At the bottom of the pyramid are **primary data** such as PCB levels in individual fish or the phosphorus loading from a particular municipality on a particular day. Such data provide the scientific underpinnings to any conclusion in regard to achieving a desired outcome. Basic data can be statistically evaluated and then combined to yield **processed** or **analyzed data** such as the average annual concentration in lake trout or the annual phosphorus loading to a lake from all municipalities.

Such basic data and information are the scientific link to the Great Lakes Water Quality Agreement, specifically the water quality objectives in Annex 1 and the phosphorus loading targets in Annex 3. These are usually understandable by scientists but often not by the general public. Knowing that the PCB level in lake trout is X mg/kg does not answer the questions of whether the fish are safe for human consumption or whether the fish can reproduce naturally. A set of values, based on scientific observation, is required to conclude whether X mg/kg is good or not.

Analyzed data can, in turn, be aggregated, combined, or integrated in some way into an **indicator** to represent the current state of a system, to measure the amount of departure from established norms, or to forecast, by extrapolation, changes in the immediate or more distant future. However, in many cases, analyzed data can serve this function without any aggregation. As discussed earlier, an indicator serves as a barometer of the general "health" of the system. Indicators are bridges between technical data and definitive conclusions about achievement of a desired outcome.

Indicators, in turn, can be aggregated into indices. Unlike an indicator, an index aggregates qualities or properties that are not necessarily equivalent, *e.g.* the underlying data and information describe rather diverse properties with a range of measurement units (*e.g.* mg/L, organisms/m^2, km of shoreline, employment rate, commercial value). Because of their empirical nature, indexes have practical shortcomings, including the challenge to clearly articulate their underlying rationale, their tendency to obscure the tangible scales associated with their component indicators, and questions about the procedure to "weight" the component indicators.

The Task Force recognizes that indexes are not necessary for the Commission to evaluate progress toward desired outcomes. Individual indicators, on clearly understood scales, are generally sufficient to answer the public's fishable, swimmable and drinkable questions. Nonetheless, indexes are an appropriate topic for future consideration.

STRESSES

A logical way to achieve desired outcomes is to deal with the stresses that impact on ecosystem integrity. A stress can be defined as anything that affects the functioning of a living system. A wide variety of stresses -- beneficial and/or adverse -- can impact the desired outcomes. Stresses can take numerous forms. They can be living or non-living and operate at the ecosystem, community, population, individual or cellular level. To achieve some desired outcomes, adverse stresses must be eliminated. To achieve other desired outcomes (*e.g.* natural succession), stresses must not be interfered with.

The Task Force considered five key stresses:

1. **Biological contamination: exotic (non-native) species.** The normal functioning of ecosystems can be disrupted when non-native species and forms are introduced, displacing and outcompeting native species and forms, and destabilizing the biological system.

2. **Chemical contamination: nutrients.** Cultural eutrophication can accelerate the natural aging process of a water body, resulting in loss of beneficial uses and undesirable biotic changes.

3. **Chemical contamination: persistent toxic substances.** These contaminants are associated with and believed to cause a variety of problems in biota, including tumours, reproductive abnormalities, altered biochemical function, and fish consumption advisories.

4. **Physical alterations.** Because of its connection with the aquatic system, changes to the physical landscape affect dependent species.

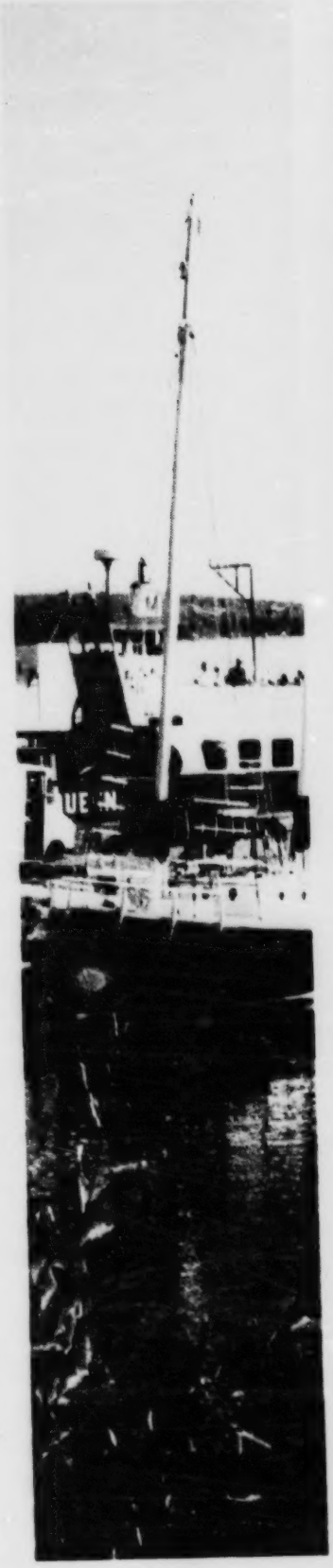
5. **Human activities and values.** Economic, societal, technological and related decisions are manifested in socio-economic, physical, chemical and biological changes and stresses.

Each stress is more fully defined in Appendix D. The Task Force reiterates here that humans, by virtue of the way they live, impact the natural components of the ecosystem. The reciprocal is, of course, also true. Human actions and values manifest themselves through stresses to, and changes in the physical, chemical and biological characteristics of the ecosystem.

There are other stresses -- known and unknown -- and all are interactive and interrelated. The particular stresses under consideration dictate the type of data and information that must be collected, processed and integrated in order to evaluate progress toward, and achievement of a desired outcome.

CHAPTER 5

EVALUATION OF AGREEMENT PROGRESS



This chapter presents the product of the Task Force's endeavours: a detailed narrative characterization for each of the nine desired outcomes introduced in Chapter 4. Specifically it provides:

- A narrative statement for each desired outcome.
- Background information, including relevance to the Agreement and delisting guidelines for impaired beneficial uses.
- Relevant impacting stresses.
- Indicators and measurements which can be used to evaluate progress toward, and achievement of the desired outcome and, hence, the Agreement goal of ecosystem integrity.

The Task Force developed this organizational scheme and underlying logic from discussions at the Indicators Workshop and further developed it through subsequent deliberations, as described in Chapter 4. Workshop participants also provided a wealth of information on desired outcomes, indicators, and primary data that should be collected or measured. The information presented below is drawn largely from their advice which is summarized in the LURA Report (Appendix E). In drawing upon the workshop information, the Task Force endeavoured to follow a consistent terminology and organization.

In "mining" the workshop deliberations, the Task Force limited itself to selected desired end points and associated indicators and measurements. A wealth of information remains in Appendix E for the reader's consideration. The material presented here is representative, intended to show the type of data and information required, and how such measurements can be logically used in the context of Agreement progress and desired outcomes.

The Task Force endeavoured to limit the indicators and measurements to a reasonable number. It also considered the possibility of a single number -- or index -- which could directly convey to the public and to the decisionmaker the status of the desired outcome. After considerable deliberation, the Task Force concluded that a single number or indicator is simply inadequate and probably misleading. A suite of indicators and measurements is necessary to do justice.

For most desired outcomes, there are multiple stresses. There are several possible indicators associated with each stress itself, the environmental consequences of the stress, associated ecosystem effects or human health effects and, finally, the societal responses. In other words, there is a group of indicators that are related in a PSR (pressure-state-response) model (as espoused by Environment Canada) or via a "spectrum" (as described by the U.S. Environmental Protection Agency).

The Task Force proposes indicators and measurements as listed below that are responsive to the stresses impacting each desired outcome as well as representative of the PSR and "spectrum" philosophies. Thus, the proposed suite for each desired outcome includes indicators and measurements that can respond to the four questions posed in Chapter 2:

- What is happening in the environment?
- Why is it significant?
- Why is it happening?
- What are we doing about it?

For each desired outcome and associated indicators and measurements, the Task Force applied the concept of ecosystem type and scale, following the ecological perspectives (community, process-function, landscape and population) introduced in Chapter 3. These concepts help clarify how the ecosystem is perceived, and how one interprets what is perceived through the indicators and measurements chosen. The concepts are implicit in the following discussion for each desired outcome.

In the selection of indicators and measurements, the Task Force considered the criteria introduced in Chapter 2. Clearly, no one indicator or measurement meets each and every criterion. However, those presented here are appropriate and necessary for each desired outcome. Further, in selecting indicators and measurements, the Task Force did not arbitrarily limit indicators to those for which data are presently being collected, but considered the broader question of whether the information was necessary to evaluate progress.

The Task Force also did not delve into the questions as to which specific data should be collected, how such data should be reported, or who should provide the data. The only stipulation the Task Force makes is that the data should be relevant to the desired outcome and in a form amenable to allow the Commission to conduct and fulfill its evaluative responsibilities.

This report, and this chapter in particular, thus constitute a guide for what data and information governments should provide to the Commission. The organizational format contained herein provides a guide to facilitate straightforward evaluation by the Commission (and others) of Agreement progress. This framework also provides flexibility for discussion and agreement on desired outcomes, appropriate indicators, and relevant data and information.

The Task Force observes that most of the measurements which support the indicators consist of quantifiable data and information which are currently available. Some data and some indicators are applicable to more than one desired outcome.

Other organizations may wish to assemble data and information to report on and evaluate Agreement progress. Such external interpretation may become more necessary in the current era of fiscal restraint and program cutbacks. The Task Force commends its framework for such use.

DESIRED OUTCOME: FISHABILITY

This desired outcome focusses on human consumption of Great Lakes fish, a significant natural resource in the basin. The Task Force defines fishability as:

There shall be no restrictions on the human consumption of fish in the waters of the Great Lakes basin ecosystem as a result of anthropogenic (human) inputs of persistent toxic substances.

Fishable means that a particular fish species is wholesome and fit to be consumed by humans. Wildlife consumption of fish (for instance by birds) is incorporated into the desired outcomes for virtual elimination and biological community integrity and diversity, both of which are discussed below.

Background

Starting in the 1970s, governments in Canada and the United States found it necessary to inform anglers that consumption of certain preferred fish species may increase health risks. The resulting health problems may be small or could lead to birth defects and cancers. The advice varies from not eating certain kinds of fish in any amount to limited consumption over extended periods of time. The advice can differ for different groups of individuals, being more restrictive for women of childbearing age and for children.

Persistent toxic substances produced, discharged or deposited in aquatic ecosystems become more concentrated in higher levels of the food web. This "biomagnification" can make fish unsuitable for human (and wildlife) consumption. Fish with high concentrations of fat (*e.g.* salmon, trout) tend to become relatively more contaminated than those with lower fat (lipid) levels. Older fish, because they are exposed to contaminants for longer periods of time, are also generally more contaminated. These relationships lead to complex Great Lakes sport fish consumption advisories.

The public tends to equate healthy, uncontaminated fish with healthy ecosystems. Accordingly, the Commission adopted as two of its 14 delisting guidelines:

- *When contaminant levels in fish and wildlife populations do not exceed current standards, objectives or guidelines, and no public health advisories are in effect for human consumption of fish or wildlife. Contaminant levels in fish and wildlife must be due to contaminant input from the watershed.*

- *When survey results confirm no tainting of fish or wildlife flavour.*

Stresses

Inputs of persistent toxic substances continue to impact this desired outcome. There are four major sources or pathways for contaminant entry to, or availability in the Great Lakes basin environment:

- Direct point source discharges from municipal and industrial sources.
- Diffuse discharges resulting, for example, from surface runoff of pesticides or hazardous leachates.
- Long- and short-range aerial transport and deposition of contaminants from inside and outside the basin.
- Sediment resuspension, facilitating contaminant reentry into the food chain.

Indicators and Measurements

The Task Force proposes the following indicator to evaluate progress toward the desired outcome of fishability:

- Fish consumption advisories.

This indicator has three questions that need to be answered for each lake:

1. Does the lake have any fish consumption advisories? If yes, then answer 2 and 3.
2. For each Great Lake, what is the total number of sport or commercial species that have advisories?
3. For each Great Lake, what is the total geographic area that is restricted for commercial fishing because of fish consumption advisories?

The Task Force proposes that lake-specific indicators be established to show progress towards unrestricted consumption. Initially, few species will conform to the goal. However, as conditions improve, more and more species of increasing size and age will become more acceptable or more fishable.

This indicator is based on a large body of chemical contaminant data. Much of the data that need to be assembled to provide lake-specific summaries for the indicator are owned by the eight Great Lakes states and Ontario. The Parties need to collect, collate and summarize the information in order to report on the status of a particular lake. As chemical contaminant levels in fish decrease, so will the number of fish consumption advisories.

Discussion

The indicator for this desired outcome -- fishability -- complements and is consistent with the indicators and measurements for the outcomes of virtual elimination of inputs of persistent toxic substances and also biological community integrity and diversity. The fishability indicator is not intended to serve as an absolute or quantitative measure of the health of the fish (for example, natural propagation) or its suitability for consumption by wildlife or other fish; those considerations are within the purview of the two other desired outcomes just noted. Fish consumption advisories set for human consumers do not necessarily protect piscivorous wildlife such as bald eagles and mink.

Fish consumption advisories exist in every Great Lake and they occur with greater frequency and for more species in the more contaminated ecosystems. As ecosystems improve because contaminant inputs are reduced, fish consumption advisories will also decrease. Progress toward the desired outcome will vary among the lakes, requiring fishability indicators for each lake.

The restoration goal is for all fish to be considered safe to eat for humans and wildlife. All jurisdictions collect and distribute information and data that relate to human consumption of Great Lake fish. The Task Force has avoided recommending an indicator that would require many jurisdictions to acquire new data at a time when it is difficult to maintain old monitoring programs.

The Task Force notes that there is no one uniform sport fish consumption advisory in the Great Lakes basin. Different jurisdictions advise anglers of the risk of eating contaminated fish in different ways. The Task Force encourages initiatives underway to produce uniform advisories that promote protection of human health, but concludes that this is unlikely to happen quickly. Irrespective of the approaches, the goal for all jurisdictions is to be

able to report that there are no advisories resulting from contamination by persistent toxic substances for any fish.

The value of the above indicator as a measure of progress towards the desired fishability outcome will only be realized when comparisons are made to similar data from previous years. Substantial overall progress has been made since the first advisories were issued and, therefore, the reference date for this indicator should be 1980. A true picture of overall progress towards the desired outcome would require historical data to be summarized and reported.

DESIRED OUTCOME: SWIMMABILITY

This desired outcome focusses on human recreational use of the waters of the Great Lakes basin. The intent is safe, full-body water contact activities at public beaches and elsewhere along appropriate shallow shorelines. The Task Force recognizes that human activities and natural factors (such as weather conditions or strong currents) may preclude swimming. The Task Force bases this desired outcome only on the former and therefore defines swimmability as:

No public bathing beaches closed as a result of human activities or, conversely, all beaches are open and available for public swimming.

Background

Annex 2 of the Agreement includes three beneficial use impairments that relate directly to the swimmable outcome, and the Commission has adopted corresponding delisting guidelines:

- *Beach closings. "When waters, which are commonly used for total-body contact ... recreation, do not exceed standards, objectives, or guidelines for such use."*
- *Eutrophication. "When there are no persistent water quality problems ... attributed to cultural eutrophication."*
- *Degradation of aesthetics. "When the waters are devoid of any substance which produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor. ..."*

Stresses

The primary stresses affecting the swimmability desired outcome are associated with human activities, such as population growth, urbanization, and agricultural and industrial development.

Indicators and Measurements

The Task Force proposes the following indicator to evaluate progress toward the desired outcome of swimmability:

- Beach closings, measured in median number of consecutive days closed for a given year.

Government authorities can base the closure of public beaches on a number of measurements that reflect the stresses associated with human activities as well as the beneficial use impairments noted above. The Task Force proposes the following suite of five measurements relevant to swimming activities at public beaches:

- Coliform count
- Turbidity
- Phosphorus concentrations
- Aesthetics
- Beach characteristics.

The first three are quantifiable and should be obtainable from existing data sources, and the last two can be obtained by visual observation and/or public opinion surveys. Additional measurements may be warranted for selected local swimming areas that may be impacted by municipal or industrial effluents containing, for instance, metals or acid that could cause human injury.

Discussion

A number of complications are associated with the measurements and their relationship to human activity. Since many different government units provide public beaches, identification of all data sources may be a challenge. Even if the data are available, the underlying decisionmaking criteria may be inconsistent from one jurisdiction to another. In reporting changes in the number of beach closures over an extended period of time, care must be taken to ensure that the number of closures reflects a change in environmental conditions and not a policy change in the decisionmaking criteria.

Further, beach closures may not be based on actual poor water quality but on suspicion of poor quality. This

reflects the desire to take a cautious approach. For example, coliform count is only a surrogate for the potential presence of pathogens that could cause human illness. In addition, the measurements noted above may also reflect non-human stresses, such as turbidity caused by storms or bacterial contamination by waterfowl.

There is room for additional research to correlate more directly human illness with direct body contact, to establish background levels of human diseases associated with exposure to degraded water conditions, and to establish a level of acceptable risk. It would also be desirable to have basinwide uniform decisionmaking criteria.

Although such information could strengthen the information base and decisionmaking, the Task Force believes the five measurements presented above are preferable for this desired outcome because they are easily quantifiable at reasonable cost and in a timely manner. Regulatory agreement is relatively easy to secure, and the measurements are understood by the public.

DESIRED OUTCOME: DRINKABILITY

This desired outcome focusses on human use of a natural resource and, because of human consumption considerations, is more applicable to treated water rather than raw water. Therefore, the desired outcome is defined as:

Treated drinking water is safe for human consumption; human activities do not result in application of any consumption restrictions.

Sources of water for human consumption include the Great Lakes, other surface waters in the basin, and groundwater. This desired outcome applies to municipal drinking water treatment plants and, for groundwater sources, public / communal wells.

Background

Annex 2 of the Agreement identified "restrictions on drinking water consumption, or taste and odour problems" as an impaired beneficial use. The Commission in turn developed the following delisting guideline:

> *For treated drinking water supplies: 1) when densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances do not exceed human health objectives, standards, or guidelines; 2) when taste and odor problems are absent; and 3) when treatment needed to make raw water suitable for drinking does not exceed the standard treatment used in comparable portions of the Great Lakes which are not degraded (i.e.) settling, coagulation, disinfection.*

Stresses

Three stresses impact this desired outcome:

- Microorganisms (*e.g.* bacteria) directly impact health of consumers.
- Nutrients contribute to plant growth which, in turn, increases algal biomass. Excess of certain algae (*e.g.* blue greens) results in taste and odour problems.
- Anthropogenic chemicals, especially toxic and persistent toxic substances, can impact the health of consumers or contribute to taste and odour problems.

Indicators and Measurements

Most measurements proposed here focus on treated drinking water. However, since conventional treatment may not remove certain organic chemicals that adversely impact human health, some measurements focus on raw water quality. The following components are easily measurable at reasonable cost and are interpretable in terms of the desired outcome. The following suite of measurements can serve as the indicators:

- Bacterial count in treated drinking water, including fecal coliform.
- Reports of human illness or infectious diseases due to consumption of treated water.
- Number of warnings of water consumption limitation, *e.g.* the need for boiling or provision of alternative water sources.
- Incidence of taste and odour problems in treated water based on public surveys and complaints, measurement of biomass, biomass composition (*e.g.* blue green algae), and/or chlorophyll.
- Reports of spills, process upsets and other incidents that release anthropogenic chemicals into the raw water supply and which could threaten a drinking water treatment plant.
- Concentration of anthropogenic chemicals in the raw water.
- Treatment plant closures. The treated water may not be drinkable, even after treatment, because of raw water quality and limitations in the treatment process. A closure may be precautionary to avoid any suggestion that supplies have been exposed and that human consumers could be at possible risk.

Closures could also depend on such factors as sophistication of the water treatment process and preparedness of the operating agency to spend additional funds for contingency treatment.

- Amount of treatment at the plant (*e.g.* amount of disinfection, filtering, alum use) and the cost for additional treatment. However, other factors, such as treatment plant operation and malfunctions, can obscure the utility of this measurement as an indicator of the suitability of water for human consumption.

DESIRED OUTCOME: HEALTHY HUMAN POPULATIONS

The desired outcomes of fishability, swimmability and drinkability (discussed above) focus on human use of the Great Lakes resource. The desired outcome of healthy human populations focusses more generally on impacts on human health as a consequence of adverse environmental conditions. It is defined as:

Human populations in the Great Lakes basin are healthy and free from acute illness associated with locally high levels of contaminants, or chronic illness associated with long-term exposure to low levels of contaminants.

Contaminants include microorganisms and anthropogenically generated toxic substances. Since the three preceding complementary desired outcomes incorporate exposure pathways, these routes are not explicitly considered here. However, air as a pathway cannot be excluded.

Background

The Agreement contains numerous references that link environmental conditions to human health. For instance, Annex 12 of the Agreement states:

> *Monitoring and research programs ... shall be established at a level sufficient to identify ... [t]he impact of persistent toxic substances on the health of humans. ... An early warning system ... shall be established to anticipate future toxic substance problems. ... Research should be intensified to determine the ... significance of effects of persistent toxic substances on human health. ...*

Regarding microbiological contaminants, Annex 1 states:

> *Waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections.*

Stresses

Two principal stresses impact this desired outcome:

- Microorganisms (bacteria, protista, fungi, viruses)
- Toxic substances, especially persistent and bioaccumulative toxic substances. These may be organic, inorganic, or radiological.

These stresses may be introduced into the Great Lakes ecosystem by direct discharge of contaminants into the lakes or surface tributaries, through groundwater discharge, by atmospheric deposition, and by disturbance of previously contaminated sediments.

Indicators and Measurements

The suite of measurements proposed here relate directly to the principal stresses. Collectively, these measurements can be used to evaluate progress toward, and indicate achievement of the desired outcome:

- Number of exceedances of established standards for microbial, chemical and radiological contamination. Measurements can include, for instance, bacterial counts at public beaches and number of beach-day closures.
- Number of people affected by waterborne microbial disease such as those due to cryptosporidium, giardia and coliform.
- Toxic substance levels in human tissues, especially those of exposed populations (*e.g.* fish eaters).
- Toxic contamination levels in human breast milk.
- Number of exceedances of established air quality standards.
- Hospital admissions for acute respiratory distress of young children.

Discussion

In addition to the LURA Report (Appendix E), information is drawn from the report, *Human Health in Ecosystem Health: Issues of Meaning and Measurement*, prepared by Eyles and Cole for the Science Advisory Board's Sub-Group on Measuring Ecosystem Health.

Increasingly, research studies are finding links between exposure to environmental contaminants and a variety of

human health issues. In general, available references agree that more research needs to be done explicitly to relate environmental stresses to human health outcomes, particularly with respect to the effects of long-term exposure to complex mixtures of low levels of toxic contaminants. The measurements presented above mostly relate to episodes of severe contamination which are clearly the cause of human health effects, or to surrogate measures of body burden that have yet to be definitively linked to long-term health effects but are a cause for concern.

The Task Force considered a variety of measurements as direct indicators of the health of human populations, *e.g.* human life expectancy, morbidity, cancer rates, birth defects, and genetic and behavioural abnormalities, among others. While the Task Force recognizes the Commission's concerns in this area, the definition of proven, useful indicators is as yet premature. Such measurements may be costly to undertake, data difficult to obtain in a timely manner, or the resulting information may not be unequivocable. A number of relevant studies (*e.g.* through the U.S. Agency for Toxic Substances and Disease Registry) are underway that focus on target populations; these may yield useful indicators. Consultation with public health personnel also may elucidate appropriate direct measures of human health.

Given the limited amount of human health information available for application to this desired outcome, the Task Force also considered use of sentinel wildlife species as surrogates, *e.g.* bald eagles, herring gulls, and selected fish species for which relevant cause-effect relationships have been developed and data are easily obtained at reasonable cost. The Task Force believes that development of such surrogates would be worthwhile to support the desired outcome of healthy human populations.

DESIRED OUTCOME: ECONOMIC VIABILITY

The human component of the Great Lakes ecosystem depends for its sustenance on the natural attributes of the system and also the continued, healthy functioning of its economy. As a social and political reality, environmental protection depends on and, in turn, undergirds a strong viable economy and the human needs and aspirations that depend on that economy. Analysis of the state of the Great Lakes economy is required in order to obtain a more complete picture of the Great Lakes ecosystem.

The Task Force defines the desired outcome of economic viability as:

A regional economy that is viable, sustainable and provides adequate sustenance and dignity for the human population of the basin.

Particular attention should be focussed on that segment of the economy that is dependent on aquatic resources in the Great Lakes basin. Viability and sustainability will permit continued attention to concerns about environmental quality and ecosystem health.

Background

Economic indicators have long been used for macroeconomic planning and analysis. The key to a multidimensional overview is to identify parameters that demonstrate essential functioning of the economy and humans needs associated with it. Production and employment are two such basic, traditional measures of economic well-being on a regional scale.

The Task Force chose employment because of its links to a number of basic societal concerns, including health. The Task Force's approach may seem simplistic. It does not, for instance, engage fundamental questions about the nature of work and the ultimate sustainability of an economic policy based on the ever-present need for jobs. The use of employment as a measure does, however, reflect a current reality, and captures a range of socio-economic and political imperatives.

The Task Force chose not to pursue production as a measure of ecosystem integrity in a Great Lakes context. Production involves many factors other than the need for a basic standard of living, such as producer and consumer surpluses and raw materials policies. Production does, however, connote a level of economic strength and viability in a region. In particular, production related to an economic sector pertinent to the region and, at least in part, to the quality and management of aquatic resources in the basin is of concern due to its links to the integrity of the aquatic ecosystem and hence the Agreement.

The value of commercial and sport fishing in the basin was carefully considered as one focus for this desired outcome. Its value can be viewed as a powerful integrator of a variety of stresses on the natural system and of human values. Yet, it can also mask a variety of policy-specific causes and outcomes due to the complexity of possible causal factors such as fishery management strategies, weather trends and exotic species. Therefore, the Task Force opted not to use this measure, but suggests that it be considered further by others in the future.

The Agreement is couched in an ecosystem approach.

This is interpreted to involve human needs and impacts and, therefore, human systems, including the economy. The ecosystem approach also requires a long- as well as a short-term view. The 14 beneficial uses in Annex 2 of the Agreement by definition include an economic dimension, making it an implicit and, in some cases, an explicit component of progress under the Agreement. Further, the Water Quality Board and, by extension, the Commission, are required by the former's terms of reference to assess progress "in the light of present and future socio-economic imperatives." Yet, despite societal experience with economic indicators as measures of national economic performance, there is but a rudimentary understanding of how to measure desirable economic states and progress therein, in a sustainable development paradigm.

A number of cutting-edge studies are presently underway in this area and initial conclusions are now emerging. It is hoped that such work will be helpful. However, even that work appears to have made little progress in defining truly integrative measures of sustainable economic conditions.

In part, the answer to the conundrum lies in the realization that the true measure of human welfare, classically assumed to be economic in its essence, is in fact much broader. It is now generally held to include social, cultural and human health (physical and mental) dimensions. Some of these issues are reflected in other desired outcomes in this report, particularly the human health desired outcome, which is determined by critical social and economic dimensions as well as the presence or absence of physical disease.

Stresses

Stresses that affect the economic viability desired outcome include:

- Overall regional production and economic activity
- Relative competitiveness of regional producers
- Demand for regional products
- Health of the resource base
- World commodity issues
- Income maintenance, retraining and other employment policies
- Other exogenous economic and social policy actions.

Indicators and Measurements

The Task Force proposes the following measurement to evaluate progress toward the desired outcome of economic viability:

- The total employment in the Great Lakes basin.

Two dimensions to this measure are:

- The size of the work force, *i.e.* the number of people desiring employment
- The employment rate, *i.e.* the percentage of the work force that is employed; this is the complement of the unemployment rate.

An overall employment rate can be developed by considering employment by major economic sectors and by division into census regions in the Great Lakes basin. It may be necessary to integrate and rationalize Canadian and United States employment statistics. Because of complexity in interpretation, the level of per capita personal income has not been adopted.

In addition to the LURA Report (Appendix E), information has also been drawn from: Great Lakes Fishery Commission, *An Introduction to Economic Valuation Principles for Fisheries Management.*

DESIRED OUTCOME: BIOLOGICAL COMMUNITY INTEGRITY AND DIVERSITY

This desired outcome focusses on the ability of the biological community to function and to handle stress. Integrity refers to community health and diversity to biological populations to be protected. Biological community integrity requires consideration of chemical water quality, habitat, energy dynamics, biotic factors and processes, and hydrology. The more diverse the biological community, the more robust to withstand present and future stress.

The Task Force defines the desired outcome of biological community integrity and diversity as:

Maintenance of the ability of biological communities to function normally in the absence of severe environmental stress (ecosystem health) and to cope with changes in environmental conditions which impose stress,* i.e. *to be able to maintain their processes of self-organization on an ongoing basis (ecosystem integrity).

Maintenance of the diversity of biological communities, species and genetic variation within species.

Such diversity are the libraries of lifeforms that have successfully coped with past stresses and which are necessary to maintain the integrity of communities for the range of stresses likely to occur in the future.

As discussed in Chapter 4, ecosystems are not static but are naturally dynamic with their balance constantly changing. For this desired outcome, the Task Force considers only human-induced impact and stress.

Background

The supplement to Annex 1 of the Agreement states, with respect to lake ecosystem objectives, that:

> *Lake Superior ... should be maintained as a balanced and stable oligotrophic ecosystem with lake trout as the top aquatic predator of a cold-water community and the* Pontoporeia hoyi *as a key organism in the food chain; and ... Ecosystem Objectives shall be developed as the state of knowledge permits for the rest of the boundary waters of the Great Lakes System, or portions thereof, and for Lake Michigan.*

In other words, Lake Superior should be maintained at something like its natural state but for the other lakes, which have already been severely and probably irretrievably altered by human activity, other objectives must be defined. Clearly, the concept of ecosystem functioning needs to be tailored to regional expectations and constraints.

Although objectives for the Great Lakes other than Lake Superior have not yet been agreed upon, ecologists such as Kay and Holling make it clear that ecology alone cannot provide an answer to which of many possible states for the individual lakes is ecologically the best. In the end, this has to be a judgement based on which of the many possible states is most acceptable to humans. Nevertheless, the basic objective to maintain the lakes in a condition that preserves their integrity in the sense of their being able to maintain that state through an ongoing process of self-organization provides some constraint on the range of human choices. If the desired state is not supported by the self-organizing ability of the aquatic communities themselves, but has to be maintained by large inputs of energy or other human manipulation, it lacks integrity. It will be subject to unpredictable fluctuations and possibly total collapse into some other, perhaps less desirable, state.

Stresses

Since one objective is to have biological communities that are capable of maintaining themselves in the face of imposed stresses, these stresses are really part and parcel of the objective itself rather than factors which hinder its achievement. However, those stresses that directly attack the level of diversity of communities, species and within species variation clearly compromise the ability of the system to cope with other kinds of stress. The following stresses are believed to be the principal ones of concern:

- Destruction of habitat important to desirable species or their supporting food web.
- Introduction of exotic species, particularly those liable to displace desirable native species from the available habitat and thereby decrease diversity, or species deliberately introduced but incapable of maintaining a self-sustaining population in the habitats available and therefore incapable of forming part of a self-sustaining community.
- Overharvesting to the point of reducing populations below a minimum viable level.
- Introduction of toxic contaminants.
- Introduction of excess nutrients (*e.g.* phosphorus) to the point of making whole classes of species unviable and flipping the state of the system from benthic to pelagic.

Indicators and Measurements

Achievement of biological community integrity and diversity entails consideration of physical, chemical and biological elements of the ecosystem, as well as pressures such as resource consumption. One key to ecosystem stability are middle trophic level biota, which are regulated by a combination of top-down and bottom-up interactions; this would also allow consideration of change in food web dynamics. The Task Force proposes the following suite of measurements, which encompass both integrity and diversity, to evaluate progress toward, and indicate achievement of the desired outcome:

- Presence and abundance of selected key species within the food web, including a top predator, a mid-trophic level species, and a species at the food base
- Quantity and quality of particular habitat types (*e.g.* wetlands and spawning beds for desirable native species)
- Number and abundance of endangered native species, including fish, waterfowl, plants and invertebrates
- Cumulative number and abundance of exotic species introduced
- Fish harvest statistics *vs.* spawning biomass levels
- Toxic contaminant levels in selected fish species and in selected fish-eating birds
- Ambient phosphorus concentrations.

Discussion

In addition to the LURA Report (Appendix E), information has been drawn from the SOLEC *Integration Paper*

and numerous other references.

An unresolved public policy issue is the acceptability of this desired outcome. As presented, this desired outcome presumes a low-level or minimal human intervention. A more highly managed system, *i.e.* a higher degree of human intervention, would yield a different desired outcome and different associated indicators and measurements. The Task Force strongly favours the desired outcome as stated.

DESIRED OUTCOME: VIRTUAL ELIMINATION OF INPUTS OF PERSISTENT TOXIC SUBSTANCES

The Great Lakes Water Quality Agreement recognizes that persistent toxic substances are a major stress on, and a significant impediment to achievement of ecosystem integrity. Consistent with the requirements of the Agreement, the Task Force defines this desired outcome as:

Virtual elimination of inputs of persistent toxic substances to the Great Lakes system.

Background

"[I]n order to protect human health and to ensure the continued health and productivity of living aquatic resources and human use thereof," the Agreement calls for the virtual elimination of the input of any or all persistent toxic substances to the Great Lakes basin ecosystem. Using the Agreement as its basis, the Commission's Virtual Elimination Task Force clarified the meaning of such terms as persistent toxic substance and virtual elimination, and also presented indicators to monitor progress toward the Agreement's virtual elimination goal. The Commission, in turn, provided a more extensive definition of persistent toxic substance in its *Sixth Biennial Report* and, in its *Seventh Biennial Report*, adopted the Virtual Elimination Task Force's final report, *A Strategy for Virtual Elimination of Persistent Toxic Substances*, and commended that report *in toto* to governments.

Annex 2 of the Agreement includes six beneficial use impairments that relate directly to the persistent toxic substance outcome, and the Commission has adopted corresponding delisting guidelines:

- *Restrictions on fish and wildlife consumption. "When contaminant levels in fish and wildlife populations do not exceed current standards, objectives or guidelines, and no public health advisories are in effect for human consumption of fish or wildlife. ..."*
- *Degraded fish and wildlife populations. "When environmental conditions support healthy, self-sustaining communities of fish and wildlife at predetermined levels of abundance that would be expected from the amount and quality of suitable physical, chemical and biological habitat present. ..."*
- *Fish tumors and other deformities. "When the incidence rate of fish tumors or other deformities do not exceed rates at unimpacted control sites and when survey data confirm the absence of neoplastic or preneoplastic liver tumors in bullheads or suckers."*
- *Bird or animal deformities or reproductive problems. "When the incidence rates of deformities (e.g. cross-bill syndrome) or reproductive problems (e.g. egg-shell thinning) in sentinel wildlife species do not exceed background levels in inland control populations."*
- *Degradation of benthos. "When the benthic macroinvertebrate community structure does not significantly diverge from unimpacted control sites of comparable physical and chemical characteristics. ..."*
- *Degradation of phytoplankton and zooplankton populations. "When phytoplankton and zooplankton community structure does not significantly diverge from unimpacted control sites of comparable physical and chemical characteristics."*

Indicators and Measurements

Consistent with the requirements of the Agreement, the advice of the Virtual Elimination Task Force, and the Commission's advice to governments, the Indicators for Evaluation Task Force proposes the following suite of seven measurements to gauge progress toward, and indicate achievement of the desired virtual elimination outcome. The measurements encompass uses, inputs to the environment, presence in the Great Lakes environment, and impact or injury in living organisms. The Task Force also notes that the biochemical and biological measurements selected below should take into account established cause-effect linkages with persistent toxic substances.

- Quantities of persistent toxic substances produced, used, and disposed of
- Total loadings of persistent toxic substances to the Great Lakes system, including the contribution by source category (*e.g.* municipal, industrial) and pathway (*e.g.* atmospheric)
- Programs and measures undertaken by governments,

business and other societal sectors to reduce and eliminate the use of specific persistent toxic substances, and the results of those programs and measures
- Concentration of persistent toxic substances in non-biological ecosystem compartments (water, sediment).

In appropriate biological species in the food web:

- Concentration of persistent toxic substances in top predator fish and fish-eating birds
- Biochemical measures of changes in cellular or subcellular processes within individual organs or tissues of an organism, *e.g.* Vitamin A storage, thyroid hyperplasia, porphyrin levels, endocrine function, immune function, genotoxicity
- Measurable changes (or biological end points) in the development, behaviour, reproductive success or survival of species, *e.g.* tumours, other visible deformities.

Appropriate indicator species (particularly fish and birds) should be selected for each of the Great Lakes. The measurements should be quantifiable and reflect changes in biological structure or function.

Achievement of the virtual elimination desired outcome is marked by the absence of toxicity or other effects attributable to persistent toxic substances in naturally reproducing populations of fish and wildlife species at the top of the food web.

DESIRED OUTCOME: ABSENCE OF EXCESS PHOSPHORUS

The Task Force defines the desired outcome as:

Absence of excess phosphorus entering the water as a result of human activity.

Ambient characteristics are biological community diversity, water clarity, absence of algal blooms and no interference with human recreational activities.

Background

Objectives (expressed as the average total phosphorus concentration, measured in the spring) were proposed for the open waters of each lake or selected lake basins. Although developed and used, these have never been incorporated into the Agreement. Allowable phosphorus loadings are listed in Annex 3 of the Agreement.

The Commission developed the following delisting guideline for eutrophication or undesirable algae, that there be:

> *no persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulations, decreased water clarity, etc.) attributed to cultural eutrophication.*

Stresses

One stress impacts the desired outcome: excess nutrients. Increased nutrient loadings contribute to plant growth which, in turn, increases algal biomass. Nutrient contamination from phosphorus is serious in certain areas of the Great Lakes. Resulting algal blooms and other effects disrupt ecological processes and impair human use of the water body.

Point sources (such as wastewater treatment facilities) and nonpoint sources (especially from agricultural production) contribute nutrients, including phosphorus, that induce stress.

Indicators and Measurements

A variety of measurements provide background and support for this desired outcome. Those proposed here relate directly to the stress, the ambient characteristics, and the requirements of the Agreement. These components are easily measurable at reasonable cost and are interpretable in terms of the desired outcome. The Task Force proposes the following suite of measurements:

- Ambient phosphorus concentrations in selected areas of the Great Lakes. Measurements must take into account spatiotemporal considerations. Particular emphasis is placed on open-lake data collected in the spring of the year, and comparison should be made with the proposed Agreement objectives. Nearshore areas may be more sensitive to the effects of phosphorus and may warrant particular attention.
- Algal blooms, which characterize excess nutrient conditions. Remote sensing and satellite imagery can be used to identify blooms, as can reports of nuisance algal growth, especially along shorelines.
- Phosphorus loading and effluent information for point and nonpoint sources that can be related directly to human-induced causes.

- Costs for additional mitigation of nutrient loadings for increased point and nonpoint source controls.
- Changes in recreational activity due to excess phosphorus.

Discussion

The Task Force considered the merits of an expanded desired outcome to focus on a balanced nutrient regime, rather than the more limited desired outcome presented here. A broader desired outcome may be appropriate, given the need to consider:

- Nutrients other than phosphorus, *e.g.* nitrogen and potassium
- The impact of both high and low nutrient levels, *e.g.* to ensure sufficient nutrients to promote optimal primary production
- The radical changes being wrought on the food web and the nutrient regime as a result of zebra mussels
- The desire to infer/deduce trophic status of the lakes, and anticipate changes therein, based on a range of suitable parameters.

Development of a balanced-nutrient-regime desired outcome would be a worthwhile endeavour in support of the Agreement.

DESIRED OUTCOME: PHYSICAL ENVIRONMENT INTEGRITY

The physical environment is a critical component of ecosystem integrity, for instance to provide sufficient appropriate habitat to meet the spawning and feeding requirements of biota comprising the food web, and to minimize adverse impacts arising from land-use activities. The physical environment encompasses a broad spectrum, including wetlands, shoreline use, harbour development, stream flow alteration and agricultural land use practices, among other diverse considerations. The Task Force defines this desired outcome as:

Land development and use compatible with maintaining aquatic habitat of a quantity and quality necessary and sufficient to sustain an endemic assemblage of fish and wildlife populations.

Such landscape integrity requires attainment and maintenance of an appropriate interface between land, water and air, as well as land characteristics compatible with a range of natural and human uses.

Background

The Commission developed two delisting guidelines relevant to physical environment integrity:

- *The amount and quality of physical, chemical, and biological habitat required to meet fish and wildlife management goals have been achieved and protected.*

- *When contaminants in sediments do not exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.*

Stresses

Three stresses impact this desired outcome:

- Actions that alter habitat, *e.g.* dredging, infilling, changing drainage patterns, changing water levels, and siltation. Actions may affect biota directly, or cause indirect impacts by changing relationships in the food chain.
- Land use changes, *e.g.* due to conversion of land to agricultural, industrial, commercial, transportation, or residential purposes. Such changes can directly remove habitat (*e.g.* wetlands), or indirectly impact habitat by secondary causes.
- Alterations in shorelines and tributaries. Such changes can affect habitat of resident or migratory species.

Indicators and Measurements

The Task Force proposes the following suite of measurements to evaluate progress toward, and indicate achievement of physical environment integrity:

- Quantity and quality of habitat throughout the life cycle for critical components of the food web. Information about productivity and submerged vegetation may be useful
- Quantity and quality of wetlands
- Quantity and quality of stream base flow
- Number and extent of engineered land/water interfaces, such as hardened shoreline (breakwalls), dams, weirs, and diversions
- Land uses and land-use practices including, for example, the nature and extent of riparian vegetation, and information about land use zoning and watershed management plans.

Some of this information may not be readily available or may require some effort to access and assemble. Nonetheless, the Task Force believes that such information is

important to measuring progress toward achievement of this desired outcome.

Discussion

These diverse physical measurements must be viewed in an appropriate context, not only in relation to each other but also with consideration to chemical and biological perturbations. To interpret these measurements in terms of achievement of physical environment integrity, information is also required about the quantity and quality of habitat, wetland and stream flow necessary and sufficient to achieve this desired outcome. Also required is information about the extent of engineered interfaces the ecosystem can tolerate and the appropriate mix of land uses and land-use practices. In other words, the end points need to be clearly defined and scientifically substantiated, including consideration of spatial and temporal factors. Further, as with many measurements, changes due to natural (non-human) factors must be considered, and also whether any observed changes are relevant to achieving the desired outcome.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This report provides advice to the International Joint Commission about how it could evaluate progress under the Great Lakes Water Quality Agreement. The advice contained herein may also be useful to governments (which have the responsibility to report on the state of the Great Lakes and on progress toward achieving the Agreement purpose of ecosystem integrity) and to the public (who wish to know that their expectations are being met). The Task Force hopes that this report will promote dialogue and the development of consensus on numerous facets associated with reporting on, and evaluating Agreement progress.

The Task Force interpreted "evaluation of progress" to encompass both programmatic progress and improvements in the environmental state or condition of the Great Lakes. The effectiveness of administrative decisions and programmatic actions ultimately should be reflected in changes in environmental quality, and the state-of-the-lake indicators and measurements presented in this report can be used in that context.

The Task Force focussed on the state of the Great Lakes aquatic ecosystem and directly related considerations, as governments have through their State of the Great Lakes (SOLEC) initiative. It focussed on a relatively small number of pertinent indicators that reflect key aspects of ecosystem status. It also defined or described a number of key terms, including: ecosystem integrity, desired outcome, indicator, data and information, and stress.

In formulating its advice, the Task Force first reviewed selected initiatives in the United States, Canada, and internationally with regard to the utility of indicators for similar or related purposes (Appendix A). Although the goals of others may be articulated or focussed somewhat differently, many have an intent akin or equivalent to the Agreement purpose. These initiatives provided a solid base which the Task Force built upon. The Task Force accordingly extracted appropriate material to develop a framework within which to evaluate Agreement progress. The concept of ecosystem integrity is fundamental to a common understanding of the context for the framework and its components.

ECOSYSTEM INTEGRITY

Ecosystem integrity encompasses three major factors: the ability of an ecosystem to operate normally under normal conditions, to cope with stress, and to continue to evolve and develop (see Chapter 4). Because all components of the ecosystem are interconnected, ecosystem integrity is dependent on a wide variety of natural and human factors. Stresses that impact one ecosystem component can also impact other components, often altering them in unexpected ways. Therefore, *as a set*, desired outcomes and their associated indicators and measurements must encompass the whole ecosystem, rather than just separate components, and must focus on sustainability of the entire ecosystem.

Ecosystems are dynamic, and each of the components of the Task Force's framework must also be viewed as dynamic, changing with time. A broad and continuing dialogue to review and revise these considerations is necessary in light of the need for flexibility, the responsibilities of

governments to report ecosystem status, the Commission's function to evaluate Agreement progress, and the public's expectations for access to relevant information, accountability, and understanding and fulfillment of their expectations.

THE FRAMEWORK

The framework relates the Agreement purpose -- to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes basin ecosystem -- to a series of desired outcomes. Each desired outcome is anchored to specific Agreement requirements. The framework also incorporates stresses that impact ecosystem integrity and achievement of desired ecosystem conditions or healthy outcomes; indicators and measurements that can be used to evaluate ecosystem status and progress toward the desired outcome; and programs and policy to ameliorate stress (see Figure 1).

The framework was developed within the context of an ecosystemic approach. Information was drawn in large part from the advice developed at the Task Force's Indicators Workshop, held October 5-6, 1994 and from the comments provided by reviewers of the Task Force's draft (May 1995) report. Within this framework, data and information can be assembled to answer such questions as: Are the lakes getting better? Have we achieved fishable, swimmable and drinkable conditions?

The Task Force recommends that:

1. **Governments, the Commission, and the public adopt the *framework* and the underlying logic as presented in this report.**

These beneficiaries, in consultation, are best positioned to undertake future review and refinement of the framework. The Task Force strongly encourages stakeholder buy-in and consensus to ensure the success of implementing actions. The Commission's Water Quality Board, Science Advisory Board, Council of Great Lakes Research Managers, and International Air Quality Advisory Board may be well positioned to facilitate deliberations regarding the framework, as well as desired outcomes, plus indicators and measurements, as discussed below.

DESIRED OUTCOMES

To characterize ecosystem integrity, the Task Force identified nine desired outcomes:

- Fishability
- Swimmability
- Drinkability
- Healthy human populations
- Economic viability
- Biological community integrity and diversity
- Virtual elimination of inputs of persistent toxic substances
- Absence of excess phosphorus
- Physical environment integrity.

Each is defined in Table 4 and characterized in Chapter 5. These outcomes or goals are interrelated and, taken collectively, provide a reasonable perspective of ecosystem integrity, at least in terms of individual components, recognizing that the whole is more than the sum of the parts. The Task Force recommends that:

2. **The Commission adopt the nine *desired outcomes* and request governments to report on progress in their periodic state-of-the-lake reports in those terms.**

The Task Force encourages the use of these desired outcomes by the public. The Task Force further encourages mutual review by the Commission, governments and the public whether the desired outcomes collectively provide a sufficiently complete description of the desired state of the basin ecosystem, and are adequate to permit sufficient evaluation to allow conclusions to be drawn regarding achievement of integrity. It may be necessary to augment and refine the proposed suite of desired outcomes by adopting others. To carry this out, in addition to the Commission's Boards and Council noted above, the Lakewide Management Plan (LAMP) process, called for in Annex 2 of the Agreement, may be an appropriate avenue.

A number of additional candidate outcomes were suggested at the Indicators Workshop (see Appendix E) and by the reviewers:

- Sustainable human population density: human population densities, including recreational visitors, shall not compromise the quality of life desired regionally.

- Sustainable human values: reverence for the Great Lakes basin as a dominant cultural feature, ensuring effective environmental stewardship indicators.

- Outcomes that focus on natural resources, such as fresh water, forests, fish, biodiversity, wetlands and soil.

Articulation, characterization and consensus on desired outcomes are necessary, but the Task Force further recog-

nizes the need for a strategy to implement the outcomes in concert. The Task Force recommends that:

3. **Governments develop and submit to the Commission a *binational, multi-stakeholder strategy* to implement the suite of desired outcomes necessary to achieve the Agreement purpose.**

INDICATORS AND MEASUREMENTS

"Data and information" must be broadly interpreted to include not only "traditional" physical, chemical and biological considerations but socio-economic and other human elements as well. The Task Force endeavoured to incorporate this broader perspective into this report; in addition, governments have introduced it into their SOLEC initiative. This perspective is reflected in the indicators and measurements selected (see Chapter 5) to support each of the nine desired outcomes. The Task Force's intent was to present *examples* of the type of data and information required and how that can be focussed in terms of achieving a particular desired outcome. As such, the proffered process and logic provide guidance to governments, the Commission and the public. The Task Force recommends that:

4. **The Commission adopt the *indicators and measurements* presented in this report for each desired outcome, and request governments to provide such information in their state-of-the-Great Lakes and other relevant reports.**

Cognizant of the need for indicators and measurements to meet the criteria of relevance to the Agreement, scientific completeness and public understandability, the Task Force compared those selected with the criteria introduced in Chapter 2. Clearly, no indicator or measurement meets each and every criterion, but the suite, the Task Force believes, is appropriate and necessary. The Task Force considered -- but set aside -- other potential indicators or measurements because they did not, in the Task Force's opinion, sufficiently satisfy the selection criteria, particularly their necessity in relation to other indicators or measurements, data acquisition cost, ease of interpretation and timeliness.

Although the Task Force considers the indicators and measurements presented in Chapter 5 as needed, in and of themselves they may not be sufficient to evaluate fully achievement of each desired outcome. The Task Force urges coöperative consultation among the Commission, governments and the public to augment the indicators and measurements associated with each desired outcome, drawing on the candidates suggested in Appendix E and by the reviewers, and carefully considering the selection criteria used herein.

In turn, to ensure development and ongoing provision of information required to track progress toward the desired outcomes and fulfillment of the Agreement purpose, governments should be advised to incorporate such data and information requirements into their surveillance, monitoring and other data-gathering programs. The suite of indicators should be so configured that they, in combination, enable assessment of progress toward -- or maintenance of -- integrity at the scale of the Great Lakes basin. Many of the indicators and measurements suggested in this report lend themselves well to mapping or similar graphic presentation.

Many data and information gathering activities focus on individual components of the ecosystem. Attempts to apply an ecosystemic approach are underway within governments and international forums, and perspectives are changing. However, these efforts still tend to be conceptual, and the reality of data collection and analysis is still largely business as usual. Future prospects, given budget cuts, do not bode well for a number of fine projects that are endeavouring to apply an integrative ecosystemic approach to the many monitoring and evaluation programs in various jurisdictions, subject areas, and at various spatiotemporal scales. The Task Force supports a holistic (rather than a reductionist) view of environmental science and policy, including associated data and information activities.

There is a need to identify and publicize more widely sources of relevant data and information. Establishment of a clearinghouse may be worthwhile, possibly as a "home page" on the Internet. One caution, however, is that information overload has progressed to the point that, "We don't know what we know."

HEALTHY HUMAN POPULATIONS

The Task Force has presented indicators and measurements that generally provide indirect evidence about the health of human populations. The Task Force considered the efficacy of direct indicators, such as life expectancy, morbidity, cancer statistics, birth defects, and genetic and behavioural abnormalities. However, such measurements may be costly to undertake, or difficult to obtain in a timely manner, or the resulting information may not be unequivocable.

Confounding factors include other variables (nutrition,

genetic makeup, lifestyle factors), experimental design problems, long-term low-level exposure to contaminants, poorly defined health-effect end points, and scarcity of suitable health statistics to show spatial and temporal trends. However, a number of relevant studies underway (for example, through the Agency for Toxic Substances and Disease Registry) may yield useful indicators and measurements. Consultation with public health personnel may also elucidate appropriate direct measures of human health.

The Task Force recommends that:

5. **Governments continue to support studies designed to link human health and well being with long-term, low-level exposure to environmental contaminants.**

6. **Governments develop indicators and measurements in appropriate fish and wildlife species to serve as surrogates for evaluation of human health.**

BIOLOGICAL COMMUNITY INTEGRITY AND DIVERSITY

The Task Force has endeavoured to articulate and characterize each desired outcome. Explicit definition requires difficult choices, in particular, value-laden selection criteria that incorporate goals for human uses as well as ecosystem sustainability. The definition of desired outcome also influences programs and policy. The Task Force tempered its deliberations, recognizing that achievement of "pristine" pre-colonization ecosystem conditions is, for the most part, unrealistic.

One desired outcome posed a dilemma. The Task Force defined the desired outcome of biological community integrity and diversity as:

> *Maintenance of the ability of biological communities to function normally in the absence of severe environmental stress (ecosystem health) and to cope with changes in environmental conditions which impose stress,* i.e. *to be able to maintain their processes of self-organization on an ongoing basis (ecosystem integrity).*
>
> *Maintenance of the diversity of biological communities, species and genetic variation within species.*

The Task Force strongly favours the desired outcome as stated. The outcome relates to elimination of all relevant stresses and presumes a low-level or minimal human intervention. However, it represents *one scenario only.* An unresolved public policy issue, in the Task Force's opinion, is the broad acceptability of this desired outcome. An alternative scenario is maintenance of a highly managed put-and-take fishery.

Measurement of progress requires agreement on the goal. Since the articulation of this and other desired outcomes is very much a public policy issue, the Task Force suggests that alternative future scenarios be created for different desired outcomes, with particular attention to:

- A highly managed future regional ecosystem
- A minimally managed, self-sustaining ecosystem.

These and other alternatives can be compared and contrasted. This process should include consideration of the long-term costs and benefits of each, thereby allowing judgements to be made and decisions reached regarding consistent alternative pathways into the future. The decision regarding which approach to take should be based on economic or other policy criteria. The Task Force observes that a highly managed system may be healthy but not well. A human analogy is a diabetic, who is not "well" but is "healthy" if insulin is properly managed. A self-sustaining ecosystem is both well and healthy.

Highly developed scenario-building methodologies are available, as are competent personnel to lead such exercises in a constructive manner. The Commission could play a role in such an undertaking on behalf of basin stakeholders, in consultation with governments and various interests, to develop and advise on the definition and suitability of the desired outcome for biological community integrity and diversity. The Commission's Boards, a Commission-sponsored workshop or roundtable, or the LAMP process may be appropriate mechanisms to consider and resolve this issue.

The Task Force recommends that:

7. **The Commission lead the development of a consensus on the definition and suitability of the desired outcome for biological community integrity and diversity.**

ABSENCE OF EXCESS PHOSPHORUS

The Task Force considered the merits of a desired outcome which focussed, not just on the absence of excess phosphorus, but on the broader issue of a balanced nutrient regime. A broader desired outcome may be more appropriate and better contribute to the Agreement goal of ecosystem integrity, given the need to consider:

- All nutrients
- The impact of both high and low nutrient levels
- Radical changes in the food web and the nutrient regime wrought by zebra mussels
- The desire to deduce or infer lake trophic status, and anticipate changes therein, based on a range of suitable parameters.

The Task Force recommends that:

8. **Governments, in consultation with the public, investigate a desired outcome for a balanced nutrient regime.**

FISHABILITY

The goal for all jurisdictions should be to report that no consumption advisories are required for any fish resulting from contamination by persistent toxic substances. However, the Task Force observes that numerous sport fish consumption advisories exist in the Great Lakes basin. Different jurisdictions advise anglers on the risk of eating contaminated fish in different ways. This leads to public confusion, especially when fish of the same size, age, species and contaminant level may or may not be subject to restricted consumption, solely on the jurisdictional waters in which the fish was caught. The Task Force acknowledges the current discussions among Great Lakes jurisdictions to develop a single, uniform sport fish consumption advisory.

To ensure protection of human health and public understanding and acceptance, the Task Force recommends that:

9. **Governments continue their initiatives to develop compatible procedures and a uniform sport fish consumption advisory for the Great Lakes basin.**

SWIMMABILITY

The Task Force observes that the underlying decisionmaking criteria regarding closure of bathing beaches is inconsistent from one jurisdiction to another and that closures may not be based on actual water quality, but on suspicion of poor quality. The Task Force recommends that:

10. **Governments develop uniform basinwide decisionmaking criteria regarding the suitability of water for swimming.**

STRESSES

A wide variety of stresses -- beneficial and/or adverse -- impact desired outcomes and, hence, ecosystem integrity. The key stresses are biological contamination, chemical contamination, physical alterations, and human activities and values. Humans, by virtue of the way we live, impact the natural components of the ecosystem. Human actions and values manifest themselves through stresses to, and changes in the physical, chemical and biological characteristics of the ecosystem. Programs and actions undertaken to date have moved us closer to the desired outcomes. However, to achieve these objectives, the human factor must be explicitly considered. The Task Force recommends that:

11. **The Commission convene a conference of basin stakeholders to examine how human actions and values can be focussed to better facilitate achievement of desired objectives.**

INDEXES

Indicators can be aggregated into indexes. Unlike an indicator, an index aggregates qualities or properties that are not necessarily commensurate, *e.g.* the underlying data and information describe rather diverse properties with a range of measurement units. Because of their empirical nature, indexes have practical scientific shortcomings, including the challenge to clearly articulate their underlying rationale, their tendency to obscure tangible scales associated with their component indicators, and questions about the procedure to "weight" the component indicators.

Indexes are not necessary to evaluate progress toward desired outcomes. Selected suites of indicators and measurements are generally sufficient to answer the public's fishability, swimmability and drinkability questions. However, it may be desirable to devise selected indexes which, while suitably scientifically grounded, would readily convey information to policymakers and the public, in a manner similar to such economic indicators as the Dow Jones and the GNP (gross national product). Suggestions include an agricultural practices index, an integrated ecosystem index, a biotic integrity index, an invertebrate community index, a body burden index, and an index related to protection (or loss) of areas or features of particular environmental value.

THE SOLEC INITIATIVE

The Commission's evaluation of Agreement progress depends on the timely receipt of accurate, consistent and pertinent information. The Parties' SOLEC initiative represents a major advance in reporting on the state of the Great Lakes and on Agreement progress, and in providing the information necessary for the Commission to carry out its evaluation.

Much of the information in the Parties' 1994 SOLEC *Integration Paper* and its supporting working papers, as well as the *State of the Great Lakes 1995* report, fed directly into the Task Force's proposed framework, and identified data and information needs. The Task Force concludes that the framework and the mechanisms are in place to report on and evaluate Agreement progress.

The SOLEC initiative and the associated reports form an important part of the information base to be used by the Commission to evaluate Agreement progress. However, the Task Force suggests more specificity in terms of clearly defined desired outcomes for the Great Lakes basin ecosystem. Also implicit in the Task Force's overall advice is the need for additional or modified indicators or measurements to describe certain outcomes more clearly, as set out in this report. The Task Force encourages coöperative development of these indicators and measurements, incorporating the points raised in this report. Such development should involve the Commission, governments, and other stakeholders.

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APPENDIX A

RECENT INDICATOR INITIATIVES

INTERNATIONAL INITIATIVES

Agenda 21

The need for indicators of sustainable development was recognized and agreed to in the United Nations Conference on Environment and Development's (UNCED) set of recommendations known as Agenda 21. The development of these indicators was stressed because of the realization that commonly used indicators, such as gross national product and measures of resources and pollution flows, do not provide adequate indications of sustainability. Instead, methods are not yet in place for assessing interactions among different sectoral environmental, demographic, social and developmental parameters.

In light of this, Agenda 21 recommended that sustainable development indicators be developed by countries at the national level (and for international and nongovernmental organizations at the international level) using environmental, demographic, social and developmental information in a holistic fashion and in forms that are understandable, timely and reliable. Once these indicators are developed, they could provide solid bases for decisionmaking at all levels and contribute to a self-regulating sustainability of integrated environmental and development systems. Much of the work mentioned below is driven by the need to respond to Agenda 21.

United Nations Agencies

Indicator development work is being carried out or fostered by several UN agencies, notably the United Nations Environment Program (UNEP), the United Nations Development Program (UNDP), the United Nations Commission for Sustainable Development (UNCSD) and the United Nations Statistical Office (UNSTAT). UNEP publishes indicators in its *Environmental Data Reports.*

Organization for Economic Coöperation and Development (OECD)

OECD has an active program to develop indicators for use in its reviews of the environmental performance of member countries. These reviews are made against the international commitments or internal policy goals of the country being reviewed, hence the need for standardized policy indicators. The OECD program uses the Canadian pressure-state-response framework and The Netherlands emphasis on policy-related indicators.

North American Free Trade Agreement (NAFTA)

The North American Commission on Environmental Coöperation (NACEC), the body charged with implementing the North American Agreement on Environmental Coöperation, the environmental side agreement to NAFTA, has begun a project to develop standardized environmental indicators for reporting on issues of concern to the three signatory states. There will be a particular emphasis on indicators capable of reflecting the environmental impacts of NAFTA itself and on continent-wide issues. There will also be a focus on the border areas of the three countries, although NACEC does not intend to duplicate in any way what is already being done by existing bilateral arrangements for the management of border issues.

Other Agencies

Private agencies such as the World Resources Institute, in its biennial *World Resources Report*, and the Worldwatch Institute, in its *State of the World Report* and *Vital Signs*, have published environmental indicators as well as social and economic indicators. The World Bank, through its Environment Department, is involved in the development of statistical reporting systems (including indicators) and intends to publish them in *Monitoring Environmental Progress.*

Scientific Committee on Problems of the Environment (SCOPE)

SCOPE, a nongovernment association mainly of academics, has a project to devise a limited set of highly aggregated indicators useful for decision and policy making. It is working closely with organizations both within and outside the UN system. A 1994 international workshop, co-sponsored by UNEP and SCOPE and co-hosted by Belgium and Costa Rica, considered various indicator frameworks proposed by SCOPE, UNEP, UNSTAT and the World Bank.

UNITED STATES INITIATIVES

A number of U.S. initiatives are described below. In addition, two reports, *Environmental Quality, 23rd Annual Report of The Council on Environmental Quality*, and *Guide to Selected National Environmental Statistics in the U.S. Government* (published by the U.S. Environmental Protection Agency), enumerate U.S. "federal interagency initiatives to coordinate environmental data and analysis," and present an "inventory and summary information of [U.S.] federal environmental statistical programs."

National Environmental Policy Act (NEPA)

All U.S. federal agencies are required to embrace the national environmental goals set out in NEPA. The act addresses the worldwide and long-range character of environmental problems, requires all U.S. federal government agencies to support international programs designed to anticipate and prevent a decline in the quality of the world's environment, and makes advice and information available to state and local governments, institutions and individuals, in order to help restore, maintain and enhance environmental quality. NEPA further requires all U.S. federal agencies to utilize ecological information in the planning and development of resource-oriented projects. The environmental documents, records of decision, and other process records developed through NEPA may be a relevant source of ecological information, including indicators.

Council on Environmental Quality (CEQ)

The CEQ, established by NEPA (discussed above) and situated in the Executive Office of the President, has periodically compiled and published statistics since 1975 that can be used for environmental indicators. The most recent report devoted solely to this topic is *Environmental Trends* (1989). However, since 1986 the CEQ *Annual Report* has contained a section on environmental trend statistics, and selected graphs and maps illustrating the information. Generally, statistics are presented to indicate conditions at a point in time, or to show trends over a period of time.

Interagency support for work such as the *Annual Report* is provided by the Interagency Committee on Environmental Trends, which also published *Integrating Environmental Information* (1993), a plan for developing a state-of-the-environment report for the United States.

Environmental data and trends in the CEQ *Annual Report* cover:

- Population
- Energy
- Air Quality
- Protected lands
- Transportation
- Economy and environment
- Water
- Land, agriculture and forestry
- Wildlife and fisheries
- Environmental hazards and human health risks.

The CEQ has also developed nationwide regulations to ensure that uniform terminology is used throughout the U.S. federal government, terms such as "effects and impacts," "mitigation," "context" and "tiering" in environmental analysis and planning. The CEQ has further required that U.S. federal agencies comprehensively interpret "human environment" to include the natural and physical environment and the relationship of people with that environment. The term "effects" includes ecological (*e.g.* effects on natural resources and on the components, structures and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social and health effects, whether direct, indirect or cumulative.

Intergovernmental Task Force on Monitoring Water Quality (ITFM)

The U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS) initiated discussions on water-quality monitoring activities in April 1991; the identification of pervasive problems associated with monitoring resulted in formation of ITFM. Part of an Office of Management and Budget directive to strengthen coördination for water information nationwide, ITFM began work in January 1992. It is composed of 20 representatives of federal, state and interstate governmental groups. The Environmental Indicators Task Group is one of five task groups that support work of ITFM.

An environmental indicator is defined by this group as a:

> "measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality."

Thus, environmental indicators must be measurable with available technology, scientifically valid for assessing or documenting ecosystem quality, and useful for providing information for management decisionmaking. Environmental indicators encompass a broad suite of measures including tools for assessment of chemical, physical and biological conditions and processes at several scales. These characteristics of environmental indicators have helped to define the scope of group activities.

The Environmental Indicators Task Group used guidelines gathered from the monitoring programs of eight federal and state agencies or groups to establish a set of criteria that can be used to select biological, chemical and physical indicators that will provide information appropriate for addressing objectives of particular programs. These criteria are organized into three broad categories: scientific validity (technical considerations); practical considerations; and programmatic considerations. The candidate indicators considered by the Task Group are divided into the following groups.

- **Indicators of Biological Response and Exposure.** There are eight indicator categories (examples: fish, including problem species; assemblage; toxicity; harvesting; populations; biomass). Each category is divided into classes to illustrate the suitability of a surface-water resource for human health and aesthetics, ecological condition and economic concerns.

- **Indicators of Chemical Exposure and Response.** There are seven indicator categories (examples: oxygenation, dissolved oxygen, BOD, benthic demand, assimilative capacity), divided into the same three classes as above.

- **Indicators of Physical Habitat.** There are six indicator categories (examples: quantity of water, drainage area, water level, velocity, flow duration), again divided into the same three classes.

- **Indicators of Watershed-Level Stressors.** There are eight indicator categories (examples: land use type, human and livestock density), yet again divided into the same three classes.

Agency for Toxic Substances and Disease Registry (ATSDR)

In 1990, Congress amended the Great Lakes Critical Programs Act, which mandates that U.S. EPA, in consultation with ATSDR and the Great Lakes states, conduct research to assess the adverse health effects of water pollutants on people in the Great Lakes states. Congress appropriated funds to carry out this Great Lakes Human Health Effects Research Program for four years, starting in 1992. In that year, ATSDR awarded ten research grants to state health departments and academic institutions in the Great Lakes states.

The goals of the program are to identify human populations residing in the Great Lakes basin that may be at risk because of their contact with chemical contaminants present in one or more of the Great Lakes, and to prevent any adverse health effects.

In support of its goals, ATSDR developed a research strategy built on the five traditional elements of disease prevention: identification, evaluation, control, dissemination and infrastructure. This strategy was endorsed by the International Joint Commission's Council of Great Lakes Research Managers and was adopted by the Commission as a framework for the study of human health and other ecosystem effects in the Great Lakes basin.

The research conducted by this program will help delineate the relationships between contaminant levels in the environment, exposure pathways, tissue levels (body burden), and correlate exposure levels to potential human health effects. The evaluation and interpretation of data across all of the human health studies in this research program should provide an essential basinwide analysis of the pollution problem in the Great Lakes.

National Water Quality Assessment Program (NAWQA)

The long-term goals of the NAWQA program, administered by the USGS, are to describe the status and trends in the quality of a large, representative part of the nation's surface and ground water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. In meeting these goals, the program will produce a wealth of water quality information useful to policy makers and managers at the national, state and local levels. A major design feature of the NAWQA program will enable water quality information at different scales to be integrated. The program consists of two major components: study unit investigations and national assessment activities.

The principal building blocks of the NAWQA program are the study unit investigations of hydrologic systems that include parts of most major river basins and aquifer systems. The program will be accomplished through investigations of 60 study areas distributed throughout the United States that incorporate about 60 to 70 % of the nation's water use and population served by public water supply.

The NAWQA program will focus on integrating results from the study unit investigations and other programs to provide information at regional and national scales. The national assessment component of the program will address specific water quality issues that are of concern in many areas of the United States. A framework has been established to ensure nationwide consistency in approach to each study, in field and laboratory methods, in water quality measurements, and in supporting data requirements.

U.S. Environmental Protection Agency (EPA) Activities

National Environmental Goals Project

This project is designed to produce a set of ambitious, realistic and measurable environmental goals to be achieved by early in the next century. U.S. EPA believes that government action must be linked to measurable indicators of environmental improvement, and that setting goals will inspire coöperation and action.

Because U.S. EPA shares responsibility for environmental protection with other federal, state and local government agencies, it is seeking their participation. The goals will not be limited to any agency's statutory obligations, but should help assess the adequacy of the statutes and regulation for meeting national environmental challenges. The process will provide a more coherent basis for conducting a results-oriented dialogue with Congress.

After holding regional roundtable discussions to obtain external opinion, U.S. EPA prepared draft goals and year 2005 benchmarks for:

- Clean outdoor air
- Safe indoor environments
- Stratospheric ozone layer restoration
- Climate change risk reduction
- Clean surface waters
- Prevention of spills and accidents
- Public awareness and participation
- Healthy terrestrial ecosystems
- Restoration of contaminated sites
- Safe waste management
- Safe food
- Safe workplaces
- Source reduction and recycling
- Safe drinking water.

A sample benchmark defined for this project is "90 percent of waters will support healthy and diverse aquatic life that is native to each body of water." Goals will describe:

- Long-range condition to be achieved
- Condition of environmental benchmarks for 2005
- Measurable objectives for reducing pressure on the environment
- Actions to achieve the year 2005 benchmarks
- Current status and trends
- Government responsibilities
- Implications for society.

In June 1995, U.S. EPA's Office of Water sponsored an indicators workshop that covered an initial group of 21 indicators and provided an update on U.S. EPA water-related indicators efforts. The Office of Water also has indicators efforts specifically on biological integrity and diversity, stormwater, point source loadings and combined sewer overflows. They are also sponsoring a pilot study with about ten states on environmental indicators to examine which of the 21 indicators selected (and any others) may be appropriate for use at the state level, and also eventually for performance agreements.

Environmental Statistics and Information

U.S. EPA has developed a unifying framework for a system of environmental statistics consistent with the emerging geographic or "ecosystem approaches" to environmental decisionmaking. Characteristics of such an approach include defining geographic units, inclusion of human activities, defining and seeking sustainability, and adopting specific goals.

The proposed approach builds on Canada's and OECD's pressure-state-response (PSR) framework, enhancing it in some ways. A PSR-type model is useful because of its simplicity and wide acceptance, and that it can be applied at any scale. The main categories in this framework are:

- Pressures: underlying direct, and indirect
- State: of the global, regional and local environments; plus human health and welfare
- Responses: by governments, private sector, households and individuals; and coöperative efforts
- Effects: ecosystem, human health and human welfare.

The content of the information framework would evolve as understanding of human-environment interactions proceeds. Development of the framework would be a long-term process, requiring collaboration among the numerous stakeholders in a statistical system, both public and private. A number of initiatives in which U.S. EPA is currently involved, including the Environmental Monitoring and Assessment Program and the Environmental Goals Project, could contribute to such a framework for a system of environmental statistics. Goals are now under development for the latter.

Environmental Results and Forecasting

The concept of environmental indicators is not new. Since the mid-1970s, U.S. EPA personnel have periodically attempted to create a shift away from relying primarily on administrative measures of success toward more direct measures of environmental quality. U.S. EPA has previ-

ously proposed the "three pillars of management" which all have a strong data orientation:

- Strategic planning
- Total quality management
- Pollution prevention.

Barriers to developing environmental indicators include lack of management focus and fear of the high costs of monitoring. Nonetheless, the vision statement for environmental indicators includes:

- Publishing complete environmental reports at national and regional levels
- Full utilization of pertinent data from federal and state agencies
- Maximum use of environmental indicator data as part of U.S. EPA's accountability system
- Linking environmental indicators with strategic planning, total quality management and research efforts
- Increasing accessibility of data to U.S. EPA and the states
- Improving forecasting abilities to identify emerging environmental problems.

In the long run, this effort would benefit public education, focus attention on geographic areas, and provide better data bases for future strategic planning.

Government Performance and Results Act of 1993 (GPRA)

Indicators and outcomes play a large role in GPRA. Key activities required of U.S. federal agencies in association with this act include the development of five-year strategic plans and performance plans by the end of FY1997, and program performance reports in FY2000 based on performance indicators and goals listed in the performance plans. To prepare for these requirements, U.S. EPA began pilot studies (one on Chesapeake Bay) and other voluntary efforts such as goal-based budgeting. The National Goals Project is an integral part of the GPRA effort.

U.S. EPA has also initiated a State Environmental Goals and Indicators Project "to assist State environmental agencies in improving their environmental management capabilities by providing procedural, technical and financial assistance in the development of environmental goals and indicators into their environmental management systems." Some of the key activities of the project are the development of a 12-state advisory board, establishing and maintaining a network of environmental indicator practitioners, technical assistance, data identification and dissemination, Internet operations, and small grants.

President's Council on Sustainable Development (PCSD)

The PCSD, set up by executive order, consists of the Secretaries of Energy, Interior, Commerce, Agriculture and the Administrator of U.S. EPA, as well as chief executive officers from major corporations, the heads of nongovernment organizations and environmental groups. Over a period of time, PCSD is to develop recommendations to the President on national goals for sustainable development. Sustainable development is a manner of conducting human activity that does not sacrifice the economic, environmental or social well-being of future generations in order to provide for current generations.

There are seven task groups under PCSD which are to identify national goals:

- Sustainable agriculture
- Energy and transportation
- Natural resources
- Public linkage, dialogue and education
- Eco-efficiency
- Sustainable communities
- Population and consumption.

The PCSD's draft 1995 report identified ten national goals, addressing a wide range of topics. A number of possible indicators of progress have also been identified:

- A healthy environment: toxic materials, life expect ancy, infant mortality, safe drinking water, clean air
- Economic prosperity: economic performance, income equity, poverty, savings rate, environmental wealth, productivity
- Equity: concept woven into each element of PCSD's work
- Conservation of nature: valuable ecosystems, conservation status, nutrients and toxics, exotic species
- Stewardship: material consumption, toxics accumulation, virgin material use, renewable material use, water use
- Sustainable communities: violent crime, public parks, public participation, investment in future generations, transportation patterns
- Civic engagement: social capital, citizen participation, collaboration
- Population: population growth, status of women, unintended pregnancies, teen pregnancies
- International responsibility: treaty commitments, international assistance, environmental assistance
- Education: information access, curriculum development, national standards, community participation.

The Interagency Working Group on Sustainable Development Indicators was initiated in 1994 by representatives from the concerned agencies. It supports work of PCSD by providing a communication channel to canvass data that might be used for indicators within agencies, and to encourage the development of indicator reports. Concepts and methods related to indicator development are exchanged and analyzed.

U.S. Census Bureau

Various surveys conducted by the Census Bureau provide useful data for indicator purposes. The *Statistical Abstract of the United States*, published by the Census Bureau since 1938, endeavours to measure, with some degree of comprehension, many aspects of the United States, as a way of getting at the whole. That report serves as the model for many of today's environmental reporting efforts. Among relevant Bureau activities are:

- The collection, analysis, publication and dissemination of statistical data relating to the social and economic activities and characteristics of the United States

- Studies and reports on domestic and foreign trade, business services, industry, transportation, construction, agriculture, population and housing, and federal, state and local governments.

Other Agency Activities

In December 1994, the U.S. Department of Agriculture's Economic Research Service issued a report on *Agricultural Resources and Environmental Indicators*. That report "identifies trends in land, water, and commercial input use, reports on the condition of natural resources used in the agricultural sector, and describes and assesses public policies that affect conservation and environmental quality in agriculture."

The U.S. Department of the Interior has many indicator programs that are contained, for example, within the USGS, U.S. Fish and Wildlife Service, and the Bureau of Land Management. Although they may not be recognized as formal indicator programs, their data collection and analysis efforts provide a crucial indicators function.

CANADIAN INITIATIVES

State of the Environment Reporting Program

The State of the Environment Directorate of Environment Canada works with partners from governmental and nongovernmental organizations to develop various national state-of-the-environment reporting products. These include a national set of environmental indicators which tracks trends in the state of Canada's environment and helps measure progress toward sustainability. Environmental indicators of sustainability must be easy to understand and use, to assist decisionmakers to integrate environmental considerations into their decision processes. Consultation with stakeholders throughout the process to develop indicators and indicator packages is considered the key to the indicators' acceptance and usefulness.

Developing indicators of sustainability is a complex process. It involves an attempt to understand and express the linkages among the environment, the economy and social concerns, including human health. As work has progressed, an ecosystem approach has emerged as the most effective way of expressing these linkages.

The national environmental indicators project has been underway since 1989. A progress report in 1991 presented a preliminary set of indicators for 18 issue areas. Environment Canada began issuing regular *Environmental Indicator Bulletins* in 1992. These bulletins present not just environmental indicators but also related economic and social indicators linked in a PSR framework. They are designed to answer four questions:

- What is happening in the environment?
- Why is it significant?
- Why is it happening?
- What are we doing about it?

These questions often lead to the setting of goals for which indicators may be able to measure progress. These goals may be environmental-state goals or human activity goals, such as limits on the emission of certain pollutants or limits on harvesting. One of the key criteria for a good indicator is its utility for measuring progress towards such goals.

Environmental Indicator Bulletins are a means of reporting regularly on the national set of indicators. Since November 1992, fourteen bulletins (with accompanying technical supplements) have been released, including:

- Stratospheric ozone depletion
- Toxic contaminants in the environment: persistent organochlorines

- Urban water: municipal water use and wastewater treatment
- Urban air quality
- Energy consumption
- Climate change
- Sustaining marine resources: Pacific herring fish stocks.

Updates are issued annually. Bulletins on ten additional issues are in preparation. The bulletins deal with national or nationally significant issues or with the Canadian contribution to global issues such as climate change and ozone layer depletion. They do not deal specifically with the Great Lakes, although several do contain indicators pertinent to the condition of the lakes, *e.g.* the level of toxics in the eggs of double-crested cormorants, the level of air pollution, drinking water quality, and the level of treatment of waste water.

Statistics Canada

Statistics Canada, in collaboration with other government departments, collects, compiles, analyzes, abstracts and publishes statistical information relating to the commercial, industrial, financial, social, economic and general activities and condition of Canada as a whole, for each province and territory, and for local areas. Client groups include federal, provincial, territorial and local government departments and agencies; business; labour; academia; the media; foreign and international bodies; libraries; research institutes; a wide variety of special interest groups; and the general public. Major current activities relevant to indicators include:

- A quinquennial census of population and agriculture. The resulting information, *inter alia*, is used for various economic and social analyses, environmental studies, and private sector planning and decisionmaking
- Periodic surveys covering virtually all aspects of economic life in Canada
- Surveys of social conditions, including the labour force; justice, health, culture, and education; and working conditions
- Estimates of gross domestic product, the balance of international payments, financial flows, the national balance sheet and input-output tables
- Statistics on environment-related topics (*e.g.* the attitudes of Canadians toward wildlife), recasting existing economic, social and demographic survey data for environmental analysis purposes (*e.g.* recompiling data by ecozone or watershed), building time-series statistics from regulatory and administrative data, and constructing natural resource and environmental accounts linked to the traditional national accounts system.

A 1994 report, *Human Activity and the Environment*, provides national as well as selected regional and local data, complementary to reports published by Environment Canada and others.

Canadian Council of Ministers of the Environment (CCME)

CCME coördinates the harmonization of environmental reporting at provincial and federal levels through its State of the Environment Task Group. A core set of environmental indicators has been identified. The CCME Water Quality Guidelines Task Group has developed a general ecosystem-based Framework for Environmental Management which uses concepts such as ecosystem health and ecosystem integrity and tools such as indicators and ecosystem goals and objectives to advance ecosystem approaches to environmental management.

National Roundtable on the Environment and the Economy (NRTEE)

NRTEE brings together senior decisionmakers from across governmental, business, labour and other sectors, reflecting various perspectives. NRTEE has been at the forefront for developing sustainable development concepts and programs, including sustainable development indicators to measure progress in this policy, both generally and in specific sub-concerns such as health. NRTEE emphasizes that such indicators must measure not only environmental sustainability but economic and social sustainability as well. Similar efforts are also underway through several of the provincial roundtables and at the local level.

Despite considerable effort in exploring indicators, there has been little progress in defining integrated, operational indicators of progress in sustainable development, as opposed to indicators of progress for individual economic, social and environmental components.

International Institute for Sustainable Development (IISD)

The Winnipeg-based IISD has developed a catalogue of sustainable development initiatives, including the development of sustainability indicators. The catalogue includes a large number of governmental and academic projects. IISD has a two-year project on measuring sustainable development progress. An aim of this undertaking will

analyze how indicators of various types can be combined to measure sustainable development performance.

IISD notes that very few projects attempt to apply specific measures as sustainability indicators, because of the difficulty in defining the concept for a particular sector or geographic region, combined with constraints on data availability and monitoring systems.

Provincial Initiatives

The Ontario Ministry of Environment and Energy (MOEE) routinely issues an Air Quality Index, which combines data on sulphur dioxide, ozone, nitrogen dioxide, carbon monoxide and suspended particulates. The index provides information to the public on general air quality for 28 communities. It is used to guide requests for short-term source reductions to ensure public health protection.

Ontario MOEE and the Ontario Ministry of Natural Resources publish the *Guide to Eating Ontario Sport Fish.* The *Guide* provides advice on safe levels of sport fish consumption from Ontario waters. It presents information on contaminant levels in edible fillets, fish species, size and location, along with toxicological advice on tolerable daily intakes of specific contaminants, provided by Health Canada.

Ontario MOEE is examining the concept of a Drinking Water Quality Index for municipal supplies in Ontario.

The Ontario Roundtable on Environment and Economy set up a Transportation Collaborative to look at sustainability and climate change within Ontario's transportation sector. One of the background studies commissioned to support the collaborative work examined indicators of sustainability.

British Columbia, in its first state-of-the-environment report, produced jointly with Environment Canada, introduced a number of indicators to measure progress in environmental management. Yukon, with assistance from Canada and British Columbia, intends to do the same. Québec has produced two comprehensive state-of-the-environment reports and is involved in the development of sectoral indicators, including indicators of the biological integrity of rivers.

Business

Business constitutes another potential source of information to assess progress in achieving regional sustainable development goals. A number of corporations are developing data bases and providing environmental reports, often styled as sustainable development reports.

GREAT LAKES INITIATIVES

State of the Lakes Ecosystem Conference (SOLEC)

SOLEC represents a Great Lakes initiative undertaken by governments in fulfillment of their obligation to report on progress under the Agreement. A draft *Integration Paper* and supporting documentation were prepared which were the focus of the first SOLEC Conference, held in Dearborn, Michigan on October 26-28, 1994. The preliminary reports and the conference led to the report, *State of the Great Lakes 1995.* The SOLEC initiative is discussed in Chapter 1 in the context of the work and the findings of the Task Force.

Ontario

In December 1993, Ontario MOEE developed its first provincial state-of-the-environment report, but the report was not released. In 1993, Toronto developed a state-of-the-city report and a research agenda for Healthy City Indicators, through its Healthy City Toronto Project; Toronto's latest state-of-the-city report was released in 1995. Hamilton-Wentworth, within Vision 2020, its internationally recognized sustainable community initiative, is developing "signposts" of progress. Further, faculty at the University of Toronto have authored a three-volume study on state-of-the-environment reporting at the municipal level, including a survey of selected municipalities. A one-volume final report, available through the North York Public Health Unit, reviews all municipal initiatives across Canada.

Great Lakes-St. Lawrence Research Inventory

To promote interjurisdictional and interdisciplinary planning and coördination of research related to implementation of the Agreement, the Commission's Council of Great Lakes Research Managers compiled and published information about current research activities in the Great Lakes-St. Lawrence River basin for 1990-91 and 1991-92. In 1994, the U.S. National Oceanic and Atmospheric Administration and Ontario MOEE jointly assumed responsibility for the inventory. This effort aims to determine the status of Great Lakes research, to show how the research reflects the current needs of the basin community, and to evaluate how research has addressed the goals and objectives of the Agreement. The research topics, as well as identified research and information needs are, in themselves, indicators of progress under the Agreement. The research results provide relevant data and information for evaluation of progress in respect to specific goals or desired outcomes, as discussed in Chapter 5.

Stewardship Indicators

Health Canada and U.S. EPA have sponsored an initiative aimed at developing measurable indicators of stewardship for the Lake Ontario basin. The development work is based in the Department of Natural Resources at Cornell University and is supported by a binational advisory committee composed of agency and university members. Through a mail survey methodology, four types of potential indicators are being developed, focussing on stewardship:

- Motivations: what prompts people's inclination toward environmental stewardship
- Intentions: the extent to which people would like to engage in good stewardship
- Behaviours: the extent to which people exhibit stewardship actions
- Barriers: factors preventing intentions from equalling behaviours.

This effort grew out of work of the binational Ecosystem Objectives Work Group, Stewardship Subcommittee. As of spring 1995, a final report regarding an Ontario pilot-test of potential indicators was being prepared, and the New York pilot-test was scheduled pending review of the survey instruments by the Office of Management and Budget.

APPENDIX B

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APPENDIX C

INDICATOR SELECTION CRITERIA

This appendix summarizes indicator selection criteria developed by the Council of Great Lakes Research Managers, Eyles and Cole, and the Intergovernmental Task Force on Monitoring Water Quality. The reference citations are:

- Council of Great Lakes Research Managers, 1991. *A Proposed Framework for Developing Indicators of Ecosystem Health for the Great Lakes Region.* International Joint Commission, Windsor, Ontario. 47 pp.

- Eyles. J. and D. Cole, 1995. *Human Health in Ecosystem Health: Issues and Meaning and Measurement.* Monograph prepared for the Great Lakes Science Advisory Board, International Joint Commission, Windsor, Ontario. 145 pp.

- *Water-Quality Monitoring in the United States -- Technical Appendixes. 1993 Report of the Intergovernmental Task Force on Monitoring Water Quality.* Prepared by the Intergovernmental Task Force on Monitoring Water Quality, Interagency Advisory Committee on Water Data, and Water Information Coordination Program, Washington, D.C., January 1994.

The Indicators for Evaluation Task Force used information from these three sources to develop the indicator selection criteria presented in Chapter 2 of this report.

The selection criteria developed by the Council and by Eyles and Cole has also been published in:

- *1993-95 Priorities and Progress under the Great Lakes Water Quality Agreement.* International Joint Commission, Windsor, Ontario, August 1995. 184 pp.

from which the information presented below has been extracted.

ECOSYSTEM HEALTH INDICATOR SELECTION CRITERIA
DEVELOPED BY
THE COUNCIL OF GREAT LAKES RESEARCH MANAGERS

Biologically relevant	••• *i.e.* important in maintaining a balanced community
Socially relevant	••• of obvious value to and observable by shareholders or predictive of a measure that is ...
Sensitive	••• to stressors without an all-or-non-response or extreme natural variability
Broadly applicable	••• to many stressors or sites
Diagnostic	••• of the particular stressor causing the problem
Measurable	••• *i.e.* capable of being operationally defined and measured, using a standard procedure with documented performance and low measurement error
Interpretable	••• *i.e.* capable of distinguishing acceptable from unacceptable conditions in a scientifically and legally defensible way
Cost-effective	••• *i.e.* inexpensive to measure, providing the maximum amount of information per unit effort
Integrative	••• summarizing information from many unmeasured indicators, one for which ...
Historical data are available	••• to define nominative variability, trends, and possibly acceptable and unacceptable conditions
Anticipatory	••• *i.e.* capable of providing an indication of degradation before serious harm has occurred, early warning
Nondestructive	••• of the ecosystem, one with potential for ...
Continuity	••• in measurement over time, of an ...
Appropriate scale	••• for the management problem being addressed. For the International Joint Commission, there are three relevant spatial scales: the Area of Concern, lakewide management and the basin ecosystem and many appropriate temporal scales
Not redundant with other measured indicators	••• *i.e.* providing unique information
Timely	••• *i.e.* providing information quickly enough to initiate effective management action before unacceptable damage has occurred

INDICATOR SELECTION CRITERIA DEVELOPED BY J. EYLES AND D. COLE

Eyles and Cole use a simplified, generic approach to indicator criteria applicable both to ecosystems and human health. They proposed two sets of indicator criteria: science based and use based, with the caveats that all indicators are goal directed and that good indicator selection is dependent on specifying the problem to be measured and managed.

The **science-based criteria** are:

- **Data availability and suitability.** It is likely because of cost constraints that existing data sets must be used where possible, but it must be remembered that those data may have been collected for different purposes than now required.

- **Validity and reliability.** To be valid, an indicator must measure the phenomenon or concepts it is intended to measure. There are four types of validity:
  - Face validity (after evaluating the rationale behind indicator selection, is it a reasonable measure?)
  - Construct validity (does the measure behave as expected in relation to other variables in the scientific model in which it is being used?)
  - Predictive validity (does the measure correctly predict a situation which would be caused by the phenomenon being measured?)
  - Convergent validity (do several measures collected or structured in different ways all move similarly over time?).

  Reliability depends on the amount of error variance in an indicator measurement, and is determined by carrying out repeat measures of the same indicator.

- **Indicator representativeness.** Questions of data representativeness are quite easy to recognize, based as they are on sampling procedures, and size and population characteristics. More troublesome is the issue of indicator representativeness. Is it possible to select one or several indicators that cover the important dimensions of concern? Indicator representativeness may be enhanced by developing an index, combining indicators. However, even if the problems of combining indicators can be overcome, if the index rises or falls, it remains unstated which of its constituent indicators are rising or falling.

- **Indicator comparability.** Not only must data be available for several time periods, they must also mean roughly the same thing at those times. The sensitivity of measurement procedures or the nature of the population being studied may change.

- **Disaggregating indicators.** To be informative, indicators must be related to other variables such as age, sex, locale and various characteristics of the involved individuals or communities. If an indicator can be broken down by several variables, it tells us a great deal more, so long as the numbers do not become too small.

The **use-based criteria** for indicator selection are:

- **Goal oriented.** There should be as much clarity as possible in the definition of the relationship between the indicator and the goal (purpose, use, state) that it is meant to monitor.

- **Feasibility.** Are the data already collected? If they are, are they available for the right time periods and at the desired geographical scale? If they are not, how feasible is it to create surrogate or indirect indicators of the phenomenon of interest? If this is carried out, what happens to scientific validity? If the data are not collected, how expensive would it be to alter the information-gathering system?

- **Desirability.** Do the indicators inform on the state of the ecosystem or of health in ways that are perceived as important by those affected? Do the indicators enable residents of a particular region or the members of a particular population group to assess their needs and risks? Do the indicators enable them to make meaningful comparisons with similar groups of residents or population members? A feature of desirability is in fact credibility (a user-version of validity).

- **Gameability.** If there is to be a link between public perceptions and indicators, then we must ensure that indicators are not gameable, *i.e.* that they cannot be "gamed" or altered by those with something to gain (while others lose) from the indicator being pushed in a certain direction at a particular pace. For example, if resources for improvements in water quality are dependent on a particular level of micro-organisms, it may pay a municipality to defer reporting improvements until budgetary allocations are made.

- **Manageability.** The ability of human beings to process information is limited. Therefore, the number of indicators to be used should be as small as possible.

- **Balance.** There should be a rough balance among all of the phenomena of interest.

- **Catalyst for action.** We may choose to distinguish indicators that more or less act as catalysts for action, whether on the part of industry, government, communities or individuals. This criterion is also important in that it relates firmly to the goals of monitoring.

These criteria act as criteria for the suitability of indicators in themselves and as criteria for specific indicator selection. They enable those concerned with monitoring ecosystems and human health in the Great Lakes basin to consider matters of proof (primarily, but not exclusively the scientific list) and of prudence (primarily, but not exclusively the use list) together.

INDICATOR SELECTION CRITERIA DEVELOPED BY THE INTERGOVERNMENTAL TASK FORCE ON MONITORING WATER QUALITY

STANDARD SELECTION CRITERIA

Environmental indicators should be able to satisfy predetermined selection criteria to ensure their viability. These criteria provide a series of guidelines that shape the decisionmaking process, resulting in an indicator that meets the needs of the program. It is important to put the selection criteria into a standardized format that can be useful for nationwide programs. Standardization of the selection criteria streamlines the indicator selection process, reduces costs, prevents duplication of effort and provides consistency, thereby increasing the potential for cross-program comparisons.

CRITERIA CATEGORIES

Scientific validity is the foundation for determining whether data can be compared to reference conditions or to other sites. Data collected from a sampling site become irrelevant if they cannot be easily compared to conditions found at a site determined to be minimally impaired. A balance of factors must be obtained when considering the scientific validity of an indicator and its application in real-world situations. An indicator must not only be scientifically valid, but its application must be practical (*i.e.* not too costly or too technically complex) when placed within the constraints of a monitoring program. Of primary importance is that the indicator must be able to address the questions the program seeks to answer.

For discussion purposes, these criteria have been divided into three categories: scientific validity, practical considerations and programmatic considerations. Although discussed separately, these categories are not entirely separate entities, but rather portions of characteristics that provide some guidance in the indicator selection process.

Scientific Validity

As with any monitoring or bioassessment program, the data collected must be scientifically valid for it to be useful. The table below lists 11 guidelines identified for assisting in this determination.

Measurements of environmental indicators should produce data that are valid, quantitative or qualitative, and allow for comparisons on both temporal and spatial scales. This is particularly important for comparisons with the reference condition. Interpretation of measurements must accurately discern between natural variability and the effects induced by anthropogenic stressors. This requires a level of sensitivity and resolution sufficient to detect ecological perturbations and to indicate not only the presence of a problem, but provide early warning signs of an impending impact. The methodology should be reproducible and provide the same level of sensitivity regardless of geographic location. It should also have a wide geographic range of application and there should be an established set of reference-condition data to which comparisons can be made.

Practical Considerations

The success of a biomonitoring program is dependent on the ability to collect consistent data over the long term, and consistency is directly related to the practical application of the prescribed methodologies. The practical considerations include monitoring costs, availability of experienced personnel, the practical application of the technology, and the environmental impacts caused as a result of monitoring.

A cost-effective procedure should supply a large amount of information in comparison to cost and effort. Of significant importance is the acknowledgment that not every quantitative characteristic needs to be measured unless they are required to answer the specific questions. It may be more important to have a range of qualitative and quantitative data from a large number of sites than it is to have a small number of quantitative parameter measurements from a small number of sites. Cost-effectiveness may be dependent on the availability of experienced personnel and the ability to find or detect the indicating parameters at all locations. State-of-the-art technology is useless in a biomonitoring program if experienced

personnel are in short supply or the data cannot be collected at all of the stations. Equally important is the ability to collect the data with limited impact to the environment. Some collection procedures (*e.g.* using rotenone to collect fish) are very effective, but minor miscalculations can cause significant environmental damage. These methodologies should be replaced with less destructive procedures.

Programmatic Considerations

Stated objectives of a program are an important factor in selecting indicators. Sampling and analysis programs should be structured around questions to be addressed. Programmatic considerations simply means that the program should be evaluated to confirm that the original objectives will be met once the data have come together. If the design and the data being produced by a program do not meet the original objective(s) within the context of scientific validity and resource availability, the selected indicators and uncertainty specifications should be reevaluated.

Another important consideration is the ease with which the information obtained can be communicated to the public. It serves interest of participating agencies to gain public support for environmental programs.

SUMMARY OF INDICATOR SELECTION CRITERIA (ITFM)

CRITERIA/QUALITY	DEFINITIONS
Scientific Validity (Technical Considerations)	
Measurable/Quantitative	Feature of environment measurable over time; has defined numerical scale and can be quantified simply
Sensitivity	Responds to broad range of conditions or perturbations within an appropriate time frame and geographic scale; sensitive to potential impacts being evaluated
Resolution/Discriminatory Power	Ability to discriminate meaningful differences in environmental condition with a high degree of resolution (high signal:noise ratio)
Integrates Effects/Exposure	Integrates effects or exposure over time and space
Validity/Accuracy	Parameter is true measure of some environmental condition within constraints of existing science; related or linked unambiguously to an end point in an assessment process
Reproducible	Reproducible within defined and acceptable limits for data collection over time and space
Representative	Changes in parameter/species indicates trends in other parameters they are selected to represent
Scope/Applicability	Responds to changes on a geographic and temporal scale appropriate to the goal or issue
Reference Value	Has reference condition or benchmark against which to measure progress
Data Comparability	Can be compared to existing data sets/past conditions
Anticipatory	Provides an early warning of changes
Practical Considerations	
Cost/Cost Effective	Information is available or can be obtained with reasonable cost/effort; high information return per cost
Level of Difficulty	Ability to obtain expertise to monitor; ability to find, identify and interpret chemical parameters, biological species, or habitat parameter; easily detected; generally accepted method available; sampling produces minimal environmental impact
Programmatic Considerations	
Relevance	Relevant to desired goal, issue or agency mission (*e.g.* fish fillets for consumption advisories; species of recreational or commercial value)
Program Coverage	Program uses suite of indicators that encompass major components of the ecosystem over the range of environmental conditions that can be expected
Understandable	Indicator is or can be transformed into a format that target audience can understand (*e.g.* non-technical public)

APPENDIX D

FIVE KEY STRESSES IMPACTING THE GREAT LAKES BASIN ECOSYSTEM

1. **Non-Native (Exotic) Species.** The normal functioning of ecosystems can be disrupted when non-native species and forms, genetically introgressed, are introduced purposefully or by accident. In such situations, native species are often displaced or outcompeted, and populations become destabilized. A recent report indicates there are 139 non-native species in the Great Lakes. Well-known and harmful Great Lakes examples include:

   - Zebra mussels, accidentally introduced from ballast water discharges of ocean-going vessels. Zebra mussels are causing native unionid clams to disappear from Lake Erie (a biodiversity issue)
   - Sea lamprey
   - Carp, introduced purposefully by European settlers in the late 1800s as a highly valued species. Carp inhibit the natural re-establishment of wetlands
   - Ruffe, alewife, and smelt
   - The rooted aquatic macrophyte purple loosestrife.

2. **Nutrients.** Nutrient contamination causes a variety of problems, but eutrophication resulting from an excess of phosphorus is the most serious in the Great Lakes. While eutrophication is a natural process whereby water bodies age slowly over geologic time, "cultural" eutrophication can greatly speed the process, causing a loss of beneficial uses. Eutrophication often results in undesirable biotic changes, including excess growth of undesirable plants such as *Cladophora* plus conditions better suited to non-native species. Human sewage and agricultural wastes are significant sources of nutrients, including phosphorus, that can stress ecosystems in this manner.

3. **Persistent Toxic Substances.** The Agreement defines persistent toxic substance as "any toxic substance with a half-life in water of greater than eight weeks." The Commission's Virtual Elimination Task Force proposed four criteria -- bioaccumulation factor, persistence, chronic toxicity to aquatic organisms, and evidence of specific causality and/or injury to biota -- to identify chemicals that meet the definition of a persistent toxic substance. Perhaps the best known are PCBs, dioxins and DDT. Persistent toxic substances are associated with and believed to cause certain tumours in fish, reproductive development abnormalities in birds, alter biochemical function, and can result in fish contaminant advisories in affected areas. Fish-eating birds such as eagles, which declined dramatically when contamination was highest in the 1960s and 1970s, represent dramatic examples of the damage done to the Great Lakes ecosystem by persistent toxic substances.

4. **Physical Alterations** consist of an interrelated array of actions -- dredging, infilling, changes in drainage patterns, changes in water levels, siltation, among others -- that result in land-use changes, shoreline and tributary alteration, loss of habitat and wetland availability and function, and other changes and losses which, in turn, affect dependent species.

5. **Human Activities and Values.** Human beings, by virtue of the way they live, stress the ecosystem, thereby contributing to the four stresses noted above. Stresses can be exported to, or imported from adjacent and distant ecosystems, such as in the case of industrial air pollution. Factors include population growth, urbanization, agricultural and industrial development, recreation, and the subsequent demands which each exerts on resource value and use. The focus is economic, societal, technological and related decisions that result in the manifestation of physical, chemical and biological changes and stresses as noted above.

Note: These descriptions are drawn from material developed at the Task Force's October 5-6, 1994 Indicators Workshop, which is summarized in the LURA Report (Appendix E), and from subsequent Task Force discussions.

APPENDIX E

LURA REPORT

Disclaimer

This appendix was prepared by the LURA Group, which facilitated the Task Force's workshop. The contents constitute their summary of the information presented and the views expressed by the participants and do not necessarily represent those of the Indicators for Evaluation Task Force or the International Joint Commission.

WORKSHOP SUMMARY REPORT

INDICATORS FOR EVALUATION OF PROGRESS *under the* GREAT LAKES WATER QUALITY AGREEMENT

October 5 and 6, 1994
Cleary International Centre, Windsor, Ontario

Prepared for the International Joint Commission's Indicators for Evaluation Task Force, by:
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November 7, 1994

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INTRODUCTION

Through the Great Lakes Water Quality Agreement, first signed in 1972, revised in 1978, and amended in 1987, the governments of the United States and Canada committed themselves "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." Under Article VII of the Agreement, the International Joint Commission is charged to evaluate Agreement progress and provide relevant advice to the governments.

To fulfil its charge, the Commission requires relevant data and information, plus a context (framework) within which to operate. In 1993, the Commission established the Indicators for Evaluation Task Force to assist in the identification of necessary and sufficient data and information, and to develop a context within which the Commission can evaluate progress under the Agreement and develop advice.

Since its establishment, the Task Force has assembled and reviewed background information relating to its mandate. The Task Force also held an Issues Definition Session in December 1993 to familiarize itself with current activities in the area of indicator development and frameworks.

As a result of its initial work, the Task Force concluded that the process to identify required data and to develop a context is iterative, and that the next step was to convene a workshop to assist with the identification of indicators for evaluating progress under the Agreement. Subsequently, the Task Force retained the services of The LURA Group, a Toronto-based consultancy, to facilitate the workshop dialogue and to ensure focused and constructive discussions.

WORKSHOP PURPOSE AND FORMAT

The Indicators for Evaluation Workshop was held at the Cleary International Centre in Windsor, Ontario on October 5 and 6, 1994. The purpose of the workshop was to identify specific indicators to evaluate progress under the Agreement.

The workshop began with a background presentation by Task Force Chair Doug McTavish. He described progress made by the Task Force to date and outlined the workshop purpose and format.

After the initial plenary, the workshop format consisted of a series of five concurrent breakout sessions which were designed to identify specific indicators relating to five key stress categories:

1. Exotic species
2. Nutrients
3. Persistent toxic substances
4. Physical stresses, including land-use changes, shoreline and tributary alteration, habitat and wetland availability and function, water levels, dredging, siltation and other factors
5. Human activity and values, such as population growth, urbanization, agricultural and industrial development, recreation, resource value and use.

At several points during the workshop, oral and written reports from each breakout group were provided to all workshop participants to facilitate information sharing among the groups. The workshop concluded with a final plenary discussion on the next steps the Task Force should undertake in its work on indicator development.

The workshop agenda is given in Appendix E-1 and the list of participants in Appendix E-2.

CONTENT OF THE WORKSHOP SUMMARY REPORT

This report provides a summary of the key results of the workshop, including:

- Overall themes that emerged during the workshop discussions
- Summary reports from each breakout group on proposed indicators
- Advice from workshop participants on next steps in indicator development.

The report is intended to serve as a concise summary for distribution to workshop participants, and for consideration by the Task Force.

OVERALL WORKSHOP THEMES

During the breakout and plenary discussions, a number of overall themes emerged. These are summarized below.

INTERRELATEDNESS

- There were numerous references made by participants regarding the interrelationships among the five key stress categories and other stressors which affect the Great Lakes ecosystem. These interrelationships must be kept in mind as indicators are developed to evaluate progress under the Agreement, particularly in view of the need to take an ecosystemic, integrated approach to indicator development.

- In developing indicators, there is a need to recognize the interaction and interconnectedness between the Great Lakes ecosystem and other ecosystems. For example, the "trans-ecosystem" movement of airborne pollutants can have implications for the state of the Great Lakes ecosystem.

NEED FOR COÖPERATION

- There is a need for enhanced interjurisdictional and interagency coördination in the following areas: data collection, policy development, program development and implementation, and reporting.

NEED FOR INDICATOR INDICES

- Workshop participants identified the potential to develop new indicator indices, including:
  - An agricultural practices index
  - A habitat index (to address quality, quantity, restoration and preservation)
  - An integrated ecosystem index
  - A progress index for nutrients.

THE CHALLENGE OF HUMAN HEALTH INDICATORS

- The development of indicators for human health is particularly challenging, given the difficulty in establishing cause-effect relationships and in determining weight of evidence.

COMMUNICATIONS/CONSULTATION ON INDICATOR DEVELOPMENT

- There is a general desire among workshop participants to have continued involvement in the Task Force's work on indicator development. There is a need for the Task Force to develop an outreach strategy, including a mix of communications and consultation initiatives, relating to the next steps of its work (see below for specific suggestions from participants).

REPORTS FROM THE BREAKOUT GROUPS

Each of the five breakout groups generally followed the process outlined below to identify specific indicators to evaluate progress under the Agreement:

1. Identify desired healthy outcomes for the Great Lakes ecosystem, in relation to the stress under consideration.

2. Review the Task Force's Proposed Criteria for Selection of Indicators (see table on page 77) and revise if appropriate.

3. Identify a "long list" of potential indicators.

4. Identify and agree on a "short list" of indicators.

The following sections present the key results -- finalized desired outcomes and short list of indicators -- from each breakout group at the conclusion of their deliberations on Day 2 of the workshop.

The following breakout group reports reflect general agreement among the participants in each group.

Exotic Species

Desired Outcomes

- Prevention of unwanted introductions
- Maintain native biodiversity consistent with the natural fluctuations of the system within a 100-year timeframe.

Short List of Indicators

1) Range expansion or reduction of exotic and native species (indicator of stress and progress).

2) Detection of new species and establishment of self-sustaining populations (indicator of stress and progress).

3) Rates of extinction of species (indicator of stress and progress).

NOTE - it may be possible to develop a ratio for indicator 2 and 3.

4) Early warning/prevention/control programs in existence (administrative indicator), *e.g.*- number of programs
   - number of established barriers
   - number of pathways for exotics to enter/ move through the system.

Research List

5) Change in keystone or unique species

NOTE- this is a measure of ecosystem function; we need to increase our understanding of keystone species.

6) Costs of exotic species (including non-market costs), *e.g.*
   - cost/benefit of exotic species
   - cost/benefit of decreases in native species.

Nutrients

Desired Outcomes

- Swimming permitted in the Great Lakes
- Improved water quality
- Elimination of algae blooms
- Biodiversity
- Balanced ecosystem (including a sustainable fishery)
- Water clarity.

Short List of Indicators

NOTE - Indicators are classified below according to the information they provide. "Progress" indicators measure the beneficial effects of managing nutrient stresses such as the frequency of algae blooms. "Diagnostic" indicators measure the nutrients themselves. "Administrative" indicators relate to nutrient source management practices. "Integrative" indicators bring information from various sources together to measure overall progress. The group also raised the idea of having "early warning" indicators.

The group was generally opposed to ranking of indicators due to the importance of using a suite of indicators that give an

overall analysis of ecosystem health as it relates to nutrient stresses. If the integrative or progress indicators demonstrate that there is a problem, the diagnostic indicators are needed to find the cause of the problem. The importance of many of the indicators can also be directly related to the specific goals outlined in the Agreement.

1) Beach closings (progress)
   - measured in median number of consecutive days closed

2) Taste and odour problems (progress)
   - measured in basin days in which a significant problem is reported by drinking water facilities in each basin

3) Algae blooms (progress)
   - measures shore deposition in shore site days

4) Anoxia in Lake Erie central basin (progress)
   - measured in per cent area of anoxia

5) Dissolved oxygen standard in nearshore environments (progress)
   - measured in site days of non-compliance with the 6 mg/L specified in the Agreement (normalized for number of sites)

6) August diatom to blue green algae ratio (progress)
   - measured by biovolume ratio for each lake; based on an annual sampling in mid-August of particle size distribution combined with species analysis

7) Balanced fishery and nutrients (progress)
   - the indicator is needed but the group lacked fisheries expertise to comment in more detail

8) Loading of phosphorus (diagnostic)
   - measured in kilograms per year per lake and targets are based on the Agreement

9) Tributary nitrates concentration (diagnostic)
   - measured in pounds in spring runoff only

10) Concentration of phosphorus (diagnostic)
   - measured grams per litre in each lake

11) Ratio of nitrogen to phosphorus (diagnostic, early warning)
   - measured as a mass ratio

12) Rate of oxygen depletion in the central basin of Lake Erie (diagnostic)
   - measured in per cent area per year

13) Point source violations per permit (administrative)
   - measured in violations per permit

14) Nonpoint source agricultural best management practices (administrative)
   - measured in per cent of cropland that is using best management practices

15) Nonpoint source urban storm water best management practices (administrative)
   - measured in per cent of major urban centres with populations greater than 100,000 with best management practices for storm water management

16) Interjurisdictional coöperation (integrative)
   - an index of cooperation was deemed to be essential but group was unable to develop a measurement

17) Long-term commitment to Agreement (integrative)
   - measured in per cent of indicators which are measured and reported

18) Progress index (integrative)
   - measure of average level of success in achieving goals of the progress indicators; a success scale of 1 to 5 to be used for each of the progress indicators.

Persistent Toxic Substances

Desired Outcomes

NOTE - the following desired outcomes are in the order ranked by the group.

- Intrinsic values - public perceptions and aesthetics
- Integrity of ecosystems
- Balanced, healthy populations of fish and wildlife
- Human drinking water
- Commercial and subsistence fishing
- Angling
- Employment (regional economics)

- Dredging - recreational and economic navigation
- Swimming
- Habitat diversity
- Industrial/agricultural water supplies
- Human health.

Short List of Indicators

NOTE - the indicators for each desired outcome below are in the order ranked by the group.

Intrinsic Value - Public Perceptions and Aesthetics

1) Reductions in loadings and concentrations of chemicals
2) Reductions in inventories of toxic substances
3) Public surveys and complaints
4) Expenditures for public waste water and air dispersion treatment.

Integrity of Ecosystems

1) Index of biotic integrity could be imported to Great Lakes
2) Benthic macroinvertebrate assemblages
3) Trophic structure and flux.

Balanced, Healthy Populations of Fish and Wildlife

1) Contaminant levels in tissues
2) Population growth rates and density in most sensitive species equal to that of control areas
3) Hatchery production, egg hatchability, fledgling wasting syndrome, porphyrin levels, Vitamin A storage, thyroid hyperplasia, sex ratio in bald eagle, osprey, mink, otter, double crested cormorant, lake trout, deep water sculpin, herring gull, salmonids and other organisms
4) Viable recruitment.

Human Drinking Water

1) Compliance with drinking water standards
2) Unit cost/water treatment/cleanup
3) Contamination of well water and groundwater.

Commercial and Subsistence Fishing

1) Number of commercial fishers, tonnage of catch, economic value and end use
2) Thermodynamically valid fish consumption advisories
3) Body burdens
4) Number of closures due to persistent toxics.

Angling

1) Number of fish consumption advisories in place
2) Tissue burdens of contaminants
3) Number of complaints of deformities, tumours.

Employment (Regional Economics)

1) Numbers of employees by category of industry (*i.e.* SIC)
2) Surveys of CEOs regarding relocation plans and reasons for relocation and expansion (includes plant closures due to persistent toxics)
3) Money spent on environmental compliance relative to control orders.

Dredging - Recreational and Economic Navigation

1) Extra money spent on containment and disposal
2) Lost years in marinas (because cannot dredge due to sediment contamination)
3) Sediment toxicity.

Swimming

1) Beach closings due to persistent toxic substances.

Habitat Diversity

1) Loss of habitat specific to persistent toxic substances
2) Changes in land use (*e.g.* agriculture/construction to eliminate wetlands, transformation of wetlands)
3) Number of regulations relating to habitat.

Industrial/Agricultural Water Supplies

1) Incidence of groundwater contamination
2) Industrial water treatment costs
3) Index of crop destruction through irrigation with contaminated water
4) Data on intake water quality from users.

Human Health

1) Health statistics - exposure to persistent toxics (swimming)
2) General morbidity and mortality, reproduction and development.

NOTE - the group cautions that it is not possible to get a causal relationship and use as a policy indicator without additional research.

Physical Stresses

Desired Outcomes

- Healthy land/water/air linkages
- Landscape integrity and connectiveness
- Restoration/protection of habitat for a spectrum of life
- Adequate quantity/quality of habitats (including human habitats)
- Sustainable use of environmental capital (groundwater, forests, etc.)
- Safe and appropriate mixes of adjacent uses.

Short List of Indicators

NOTE - the indicators for each desired outcome below are in the order ranked by the group.

Healthy Land/Water/Air Linkages

1) Quantity/quality of stream base flow
2) Number of engineering land/water interfaces (dams, weirs, diversions, hardening of shoreline)
3) Productivity of certain species - bald eagle, black bear (also an indicator for restoration/protection of habitat).

Landscape Integrity and Connectiveness

1) Measure of habitat connectiveness (number of barriers - roads, fences, canals, rail)
2) Land-use planning zoning, re-zoning (also an indicator for safe and appropriate mixes of adjacent uses)
3) Resilience - time of recovery of system health following an extreme event/disturbance.

Restoration/Protection of Habitat for a Spectrum of Life

1) Acres restored to wetland condition - net gain (also an indicator for adequate quantity/quality of habitat)
2) Compliance with protection of wetlands (also an indicator for adequate quantity/quality of habitat)
3) Quality/quantity of dredged material
4) Extent of submerged aquatic vegetation
5) Productivity of certain species - bald eagle, black bear (also an indicator for healthy land/water/air linkages).

Adequate Quantity/Quality of Habitat

1) Rates of loss of particular habitat types

2) Acres restored to wetland condition - net gain (also an indicator for restoration/protection of habitat)

3) Compliance with protection of wetlands (also an indicator for restoration/protection of habitat)

4) Percentage of optimum population density - specific species.

NOTE - the group agreed that the two above desired outcomes for habitat and accompanying indicators could be combined into a single Habitat Index.

Sustainable Use of Environmental Capital

1) Acid loadings

2) Restoration of agricultural land to fallow lands

3) Measure of stream-side buffers.

NOTE - the group agreed that "restoration of agricultural land to fallow lands" and "measure of stream-side buffers" could be combined into a single Agricultural Practices Index.

Safe and Appropriate Mixes of Adjacent Uses

1) Land-use planning zoning, re-zoning (also an indicator for landscape integrity and connectiveness)

2) Incidents of spills, "accidents," "releases" relating to use and transport of human controlled and human synthesized products

3) Changes in richness - types of organisms with respect to air/water/land interface.

Human Activity and Values

Desired Outcomes

- Population - sustainable population
- Urbanization - balance between land uses
- Agriculture - sustainable agriculture
- Industrial development - balance of uses
- Recreation - ensure natural and passive recreational activities and minimize the interference with or degradation of resources
- Resource value and use - sustainable yield/self-sustaining
- Behavioural change - engrained understanding of issues through awareness, public education and training
- Economics - maintain social and economic factors
- Institutions - effective institutions based on ecosystemic decisionmaking
- Value system - modify value system to reflect desired outcomes in other categories.

Short List of Indicators

Population

1) Number of people in the basin and the level of migration (in and out of the basin).

Urbanization

1) Number of plans to eliminate and/or mitigate *known* combined sewage overflows

2) Rural to urban conversion rate (*i.e.* the number of hectares)

3) Population (*i.e.* basic demographic information).

Agriculture

1) Percentage of land under conservation tillage

2) Number of best management plans (BMP).

Industrial Development

1) Toxic Release Inventory (TRI) and National Pollutant Release Inventory (NPRI)

2) Number of annual environmental reports prepared by industry

3) Overall production levels.

Recreation

1) Number of beach closings (*i.e.* the duration of the closure and the miles of beach days closed)

2) Number of fish (and other) licenses issued.

Resource Value and Use

1) Level of biodiversity (*i.e.* the number of species)

2) Number of fish advisories issued

3) Total number of shoreline miles undeveloped in each lake and connecting channel

4) Number of watershed management plans developed

5) Number of acres (*i.e.* as a per cent of critical habitats) protected by special designation status.

Behavioural Change/Value System

1) Rate of waste generation per capita

2) Number of schools (kindergarten to university/ college level) offering environmental awareness programs.

Economics

1) Per capita income.

Institutions

1) Number of beneficial uses restored in each Area of Concern

2) Degree of agency/program integration

3) Level of human and financial resources allocated to the environment.

SUGGESTIONS FROM PARTICIPANTS ON NEXT STEPS

At the final plenary, Task Force Chair Doug McTavish thanked participants for their hard work and valuable input during the workshop. He stressed that the process the Task Force will follow to develop their advice to the Commission is iterative, and he briefly outlined the Task Force's proposed next steps:

- Based on the workshop results, develop a "white paper" that will be circulated to all workshop participants, as well as others within the Commission family -- the Water Quality Board, Science Advisory Board, and the Council of Great Lakes Research Managers -- for review and comment.

- Revise the "white paper" based on comments received, and tender a report to the Commission, along with advice about the next steps in the process to develop indicators.

- Table the report for public discussion and consideration at the Commission biennial meeting in Duluth, Minnesota, September 23-26, 1995.

He then asked participants for their advice on how to proceed. Suggestions from participants were as follows.

Workshop Results

- Consider the reports from the five breakout groups as the key product of the workshop.

Communications/Consultation

- Circulate the workshop results to participants and other key players to stimulate further discussion and input.

- Don't just send the "white paper" to those involved in LAMPs, RAPs and EMAPs and ask for comment; arrange a meeting involving these key players to get their input.

- Carefully consider when is the right time to approach regulatory agencies for their input; the report must be adequately fleshed out to enable regulators to provide effective input, but consultation must occur well before the report is a "done deal."

- Meet with the Parties to inform them of the Task Force's work and obtain their input. Then meet with other interested and affected jurisdictions.

- Provide briefings on the Task Force's work to participants at the State of the Lakes Ecosystem Conference (October 26-28, 1994) and Lake Erie Binational Steering Committee meeting (November 7-8, 1994).

- Develop an overall outreach plan to communicate and facilitate input on the Task Force's work.

- Consider a graphic presentation for the indicators for each stress category. For example, a pyramid could be used with the agglomerative indices at the top. There would be an increasing level of detail as you move towards the base of the pyramid.

Refining the Lists of Indicators

- Review the lists of indicators developed by the breakout groups, and attempt to compress and/or aggregate where possible.

- Recognize that the breakout groups have developed suites of policy indicators; there is also a need to identify illustrative indicators.

- Circulate a matrix containing desired outcomes and short lists of indicators to workshop participants to further refine the lists of indicators, and obtain further information on data availability.[1]

Other

- Ensure that there is a smooth transition between the current Commission structure to evaluate progress under the Agreement and the new structure which will emerge as a result of the Task Force's work.

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[1] This suggestion was raised in correspondence to the Task Force Chair following the workshop.

Table

CRITERIA FOR SELECTION OF INDICATORS

- Necessary and sufficient
- Data and information availability
- Costs, including a recognition of the availability of human and financial resources
- Integrative capacity
- Scientific validity
- Certainty and quality of results
- Understandability by technical and lay persons
- Policy relevance
- Ability to establish reference values, or targets to achieve.

APPENDIX E-1

WORKSHOP AGENDA

DAY 1: WEDNESDAY, OCTOBER 5

0830 - 0900	**Registration**
0900 - 0915	**Opening Remarks** Welcome, introductions, housekeeping
0915 - 1045	**Opening Plenary** Workshop purpose and needs; background presentation; charge to the breakout groups; introduction of facilitators and rapporteurs
1045 - 1100	**Break**
1100 - 1200	**Breakout Groups** (five concurrent sessions) Review charge; self-organization; approach to task; start deliberations
1200 - 1330	**Lunch** (on your own)
1330 - 1630	**Breakout Groups** (continued)
1630 - 1700	**Plenary** Brief report from each breakout group to see where we are
1700 - 1800	**Social Hour - Cash Bar** Informal discussion among participants; flip chart pages from each group will be displayed on walls **Dinner** (on your own)

DAY 2: THURSDAY, OCTOBER 6

0800 - 1000	**Breakout Groups** (continued) Five one-page progress reports, one from each group, will be distributed to all participants prior to reconvening in the breakout groups
1000 - 1020	**Break**
1020 - 1100	**Breakout Groups** (Conclusion) Finalize written reports
1100 - 1145	**Plenary** Oral reports from each breakout group
1145 - 1300	**Lunch** (on your own)
1300 - 1445	**Final Plenary** Workshop organizers and facilitators will present a synthesis of deliberations, followed by discussion
1445 - 1500	**Closing Remarks** Final comments; the next steps in the process
1500	**Adjourn**

APPENDIX E-2

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APPENDIX F

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